



1121 L Street, Suite 1045, Sacramento, CA 95814

November 15, 2010

Chairman Philip Isenberg and Council Members
Delta Stewardship Council
980 9th Street, Ste. 1500
Sacramento, CA 95814

Dear Chairman Isenberg and Council Members,

Please find attached comment letter from SFCWA sent to the Department of Fish and Game on November 1, 2010 regarding amended comments on the DFG Draft Report for your review.

Sincerely,

A handwritten signature in black ink, appearing to read "Byron Buck", is written over a light blue horizontal line.

Byron M. Buck
Executive Director

Directors

James M. Beck
*Kern County Water
Agency*

Jeff Kightlinger
*Metropolitan Water
District of Southern
California*

Bill Harrison
Dan Nelson
Jason Peltier
*San Luis & Delta-
Mendota Water
Authority*

Beau Goldie
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Water District*

Steve Robbins
Jill Duerig
*State Water Project
Contractors
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Tom Birmingham
*Westlands Water
District*



1121 L Street, Suite 802, Sacramento, CA 95814

November 1, 2010

Mr. Chad Dibble
Department of Fish and game
1416 9th Street, 12th Floor
Sacramento, CA 95814

RE: Amended Comments on DFG Draft Report: Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta

Dear Mr. Dibble:

The State and Federal Contractors Water Agency ("SFCWA") provided timely comments on October 18, 2010 regarding the California Department of Fish and Game's ("DFG") draft report "Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta" ("DFG Report"). In an effort to provide DFG with the most complete and useful information as possible, SFCWA is submitting the attached amendment to our earlier comments, which is intended as a complete replacement of the prior version.

SFCWA recognizes the short timeframe provided by the Legislature for DFG to develop its Flow Report, and the limited ability of DFG to fully consider the complete suite of actions that are necessary to improve the health of the Delta ecosystem. SFCWA and the agencies it represents look forward to continuing to work with DFG in the Bay Delta Conservation Plan ("BDCP") process to develop a well rounded package of actions that will consider future flows in combination with habitat restoration, water quality improvements, predation reduction actions, and measures to address other stressors.

Sincerely,

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**STATE AND FEDERAL CONTRACTORS WATER AGENCY
REVIEW OF THE DEPARTMENT OF FISH AND GAME DRAFT REPORT
“QUANTIFIABLE BIOLOGICAL OBJECTIVES AND FLOW CRITERIA
FOR AQUATIC AND TERRESTRIAL SPECIES OF CONCERN DEPENDANT ON THE
DELTA”
(Amended, 10-28-10)**

The Department of Fish and Game (“DFG”) issued its draft report entitled, Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta (“DFG Report”), on September 21, 2010, and requested public review.

In response, the State and Federal Contractors Water Agency (“SFCWA”) brought together a team of experts from a variety of disciplines to review the DFG Report.¹ They concluded that the DFG Report is scientifically flawed and cannot be reasonably relied on as a basis for future decision-making.

DFG provided much of the analysis used by the State Water Resources Control Board’s (“State Water Board”) in its Report on Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem (“Flow Criteria Report”).² As SFCWA explained in its written critique of the Flow Criteria Report, the State Water Board did not adhere to standard scientific principles for use and reliance on technical information. The DFG Report relied on the Flow Criteria Report without correction, thereby further perpetuating errors; and DFG did so without providing qualifying statements to acknowledge substantial scientific uncertainty and inherent limitations of the report.

The DFG Report cannot be the basis for sound agency decision-making until it is revised to address substantive technical errors, failures to follow standard scientific protocols, and the perpetuation of unfounded assumptions or hypotheses, as follows:

I. The DFG Report did not provide a biological basis for the underlying assumption that a new flow regime, without any other actions, would increase species abundance.

The State Water Board’s Flow Criteria Report and the DFG Report were developed based on an assumption by the Legislature that a new flow regime, without any other actions, could increase species abundance. However, as William E. Fleenor, William A. Bennett, Peter B. Moyle, and Jay R. Lund, explained in a written report to the State Board:

The performance of native and desirable fish populations in the Delta requires much more than fresh water flows. Fish need enough water of appropriate quality over the temporal and spatial extent of habitats to which they adapted their life history strategies. Typically, this requires habitat having a particular range of physical characteristics, appropriate variability, adequate food supply and a diminished set of invasive species. While folks ask “How much water do fish need?” they might well also ask, “How much habitat of different types and locations, suitable water quality, improved food supply and fewer invasive species that is maintained by better governance institutions, competent implementation and directed research do fish need?”³

Therefore, the Legislature asked DFG the wrong question. In its response, the DFG Report is trying to use flow to dilute pollution and nutrient loading, to compensate for the lack of available physical habitat for species, and to reduce the effect of predation, among other uses. But there is no single flow regime that can do all of those things (and even if there was, it would result in the waste and unreasonable use of

¹ The *curriculum vitae* for the experts have been provided in Attachment A.

² State Water Resources Control Board. 2010. Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem, dated August 3, 2010.

³ William E. Fleenor, William A. Bennett, Peter B. Moyle, and Jay R. Lund, *On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta*, pp. 28-29.

water). The experts testifying at the State Board's flow proceedings earlier this year agreed, and told the State Water Board that:

"If you look at only outflow criteria, I think it will be a fragmentary and insufficient response for the native fish."

Jay Lund, UC Davis
State Water Board Flow Proceedings, Day 1

"Delta outflow alone can't do the job."

Don Stevens, CSPA
State Water Board Flow Proceedings, Day 2

"Just to reiterate, everybody pretty much hit the main points, is that flow alone is not going to do the trick."

Fred Feyrer, DOI
State Water Board Flow Proceedings, Day 2

The actual flow regime that could provide additional benefits to Delta species is not contained in the DFG Report; rather, it will be developed through the development of the Bay Delta Conservation Plan ("BDCP"). The BDCP will ultimately determine the appropriate flow recommendation as it develops its plan for water project operations, thousands of acres of new habitat, and measures to control and minimize other stressors such as pollutants and predators. It is only through this holistic approach will it be possible to determine the appropriate flow regime for protecting the fishery.

II. The DFG Report did not acknowledge its substantial effect on the available water supply, effectively shutting down the water system for a state with 36.96 million people, and counting.

DFG states, "Before any specific flow criteria are implemented, the following should be considered...Balancing of the need to protect the Delta's aquatic and terrestrial ecosystem with the need for reliable water supply."⁴ The fact the available water supply was not considered in the DFG Report's development is significant. The water supply effect of the State Water Board's proposal, which is quite comparable to DFG's, would reallocate 5.5 million acre-feet from human consumption to outflow and the sea.⁵ This would be a 69% reduction in consumptive use in the upper watershed and the Delta, leaving all of northern and portions southern California, including the Bay-Area, with only 30% of their current supply. A loss of available water supply of this magnitude would be devastating to the economy and communities across the state.

Moreover, the experts agree that this massive reallocation of water resources away from human communities would not be expected to measurably increase fisheries abundance. In his oral testimony before the State Board during the flow proceedings, Dr. Bill Bennett stated, "...anyone recommending an outflow number at this time would be doing the species a „disservice," because there is no magic outflow number that can reasonably be expected to result in a measureable increase in species abundance."⁶ The logic behind DFG's proposal is therefore difficult to understand.

III. The DFG Report provides no support for its conclusion that flow stabilization harms native species and encourages non-native species.

⁴ DFG Report at p. 103.

⁵ Draft State Water Board Flow Criteria Report, Appendix B.

⁶ SWRCB Flow Proceedings, Oral Testimony, Day 2 (emphasis added)

It is not apparent what the basis is for DFG's conclusion that flow stabilization is real or that it has negatively affected the Bay-Delta's biological communities. Figure 1 (from Moyle *et al.* 2010 at p. 16)⁷ shows that the more recent hydrologic period 1986-2005 is not significantly different than previous historical periods when fish reportedly did much better. Nor does the finding make sense when one considers the multitude of other stressors in the Bay-Delta that are also harmful to native species and independent of flows, such as the *Corbula amurensis* invasion and contaminants, which have historically gone unregulated or under-regulated by State and Federal agencies, including DFG.

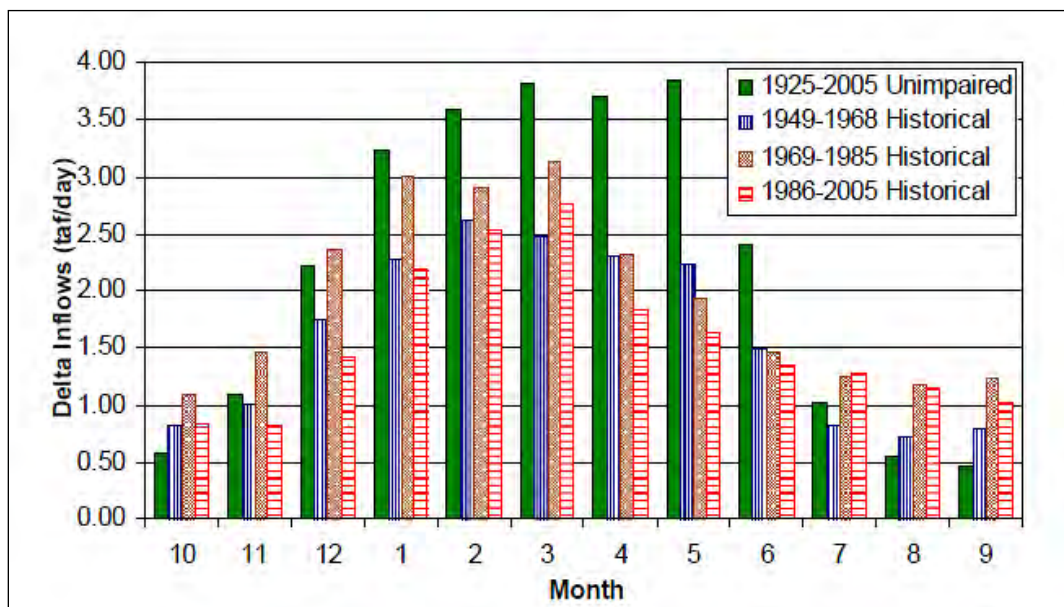


Figure 1. Averaged daily inflows in thousands of acre feet each month from Sacramento and San Joaquin Rivers showing unimpaired flows (solid green bar) and three historical periods, 1949-1968 (vertically-striped blue), 1969-1985 (brown) and 1986-2005 (horizontally-striped red), illustrating progressive changes to inflow from unimpaired conditions. Note increases in summer inflow during recent decades. Data from unimpaired boundary conditions (DWR) and historical boundary conditions (DAYFLOW) from Moyle *et al.* (2010) at p. 16.

IV. The DFG Report did not acknowledge the trade-offs amongst protected species.

The DFG Report focuses on protecting species like longfin smelt and unlisted species like starry flounder, California bay shrimp, Sacramento splittail, American shad, and zooplankton. These species are attributed with biological importance above that of the endangered winter-run Chinook salmon, the threatened spring-run Chinook salmon, and fall-run Chinook salmon. The DFG Report states that, “The criteria contained in the report should be balanced by the need to maintain cold water resources in reservoirs on tributaries to the Delta...”⁸ The fact that the cold water needs of Chinook salmon were not considered during the development of the DFG Report is significant; because the flows being proposed by DFG would create harmful thermal conditions on the mainstem of the Sacramento River that would be highly detrimental to spawning Chinook salmon. This would also create an inability to meet existing regulatory requirements for species protection. For example, the loss of storage in Shasta reservoir would cause carryover storage requirements imposed by the reasonable and prudent alternative (“RPA”) in the National Marine Fishery Service’s (“NMFS”) biological opinion on the joint operation of the Central Valley Project (“CVP”) and the State Water Project (“SWP”) (herein “NMFS BiOp”)⁹ to be violated in about three of every four years.

⁷ Moyle, Peter B, *et. al.* 2010. Habitat Variability and Complexity in the Upper San Francisco Estuary. *Delta Solutions*. <http://deltasolutions.ucdavis.edu>.

⁸ DFG Report at p. 93.

⁹ National Marine Fisheries Service Final Biological Opinion and Conference Opinion of Proposed Long-Term Operations of the Central Valley Project and the State Water Project (“NMFS BiOp”), June 4, 2009.

The causal mechanisms of elevated temperatures on spawning and rearing of Chinook salmon is well documented, whereas the causal mechanisms of Delta outflow on longfin smelt abundance are not.

V. The DFG Report relies on unpublished analyses and speculation to support conclusions regarding the importance of flow to longfin smelt (*Spirinchus thaleichthys*) abundance

The longfin smelt's relationship with X2 is often characterized as the strongest of the fish-flow relationships (Kimmerer 2002; Kimmerer *et al.* 2008; Dege and Brown 2004, Feyrer *et al.* 2004).¹⁰ The DFG Report hypothesizes that population abundance of longfin smelt is positively related to Delta outflow during winter and spring and that its population abundance as measured by the Fall Mid-Water Trawl ("FMWT") is inversely related to the number of fish salvaged.¹¹ Based on this purported relationship, the DFG Report concludes that more outflow will result in more fish.

a. Longfin abundance is more strongly correlated with food availability than with Delta outflow (X2)

The DFG Report relies heavily on the statistical correlation between the FMWT and X2 to conclude that outflow will result in increased longfin abundance; even though the predicted population response for a given X2 is rapidly diminishing, probably as a result of reduction in food supply. Indeed, correlations between longfin smelt abundance and food supplies are as good or better than the correlations between longfin abundance and X2.

Figure 2 shows log longfin FMWT from 1975 to 2006 versus *Eurytemora affinis* densities in Suisun Bay. Despite the high variance in the measurement of *E. affinis*, the relationship is as good as the FMWT relationship. Figure 3 shows log FMWT versus log total mysid shrimp. Again, despite high measurement uncertainty, the food variable is very powerful. Both *E. affinis* and mysid shrimp are well known foods for longfin smelt and thus are part of a plausible theory of cause and effect, unlike the X2 relationship for which there is no established causal mechanism. The question then becomes one of discovering why *E. affinis*, mysids, and other food sources have declined. Research indicates the answer is most likely related to changes in the phytoplankton regime (a collapse in diatom densities) and ultimately to changes in the nutrient regime. This issue is discussed in Section X.

¹⁰ Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series*, Vol 243: 39-55; Kimmerer WJ, Gross ES, MacWilliams ML. 2008. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuaries and Coasts* 32:375-389; Dege M, Brown L. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. Pages 49-66 in F Feyrer, L Brown, R Brown, and J Orsi, editors. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society Symposium, Bethesda, Maryland.

¹¹ DFG Report at p. 62.

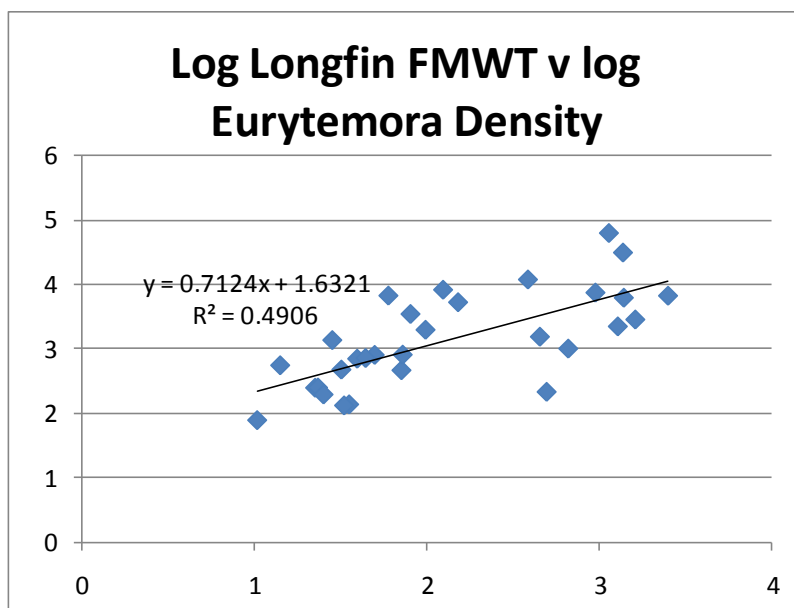


Fig. 2. Log (Longfin FMWT) v log Eurytemora Density in Suisun Bay 1975 - 2006.

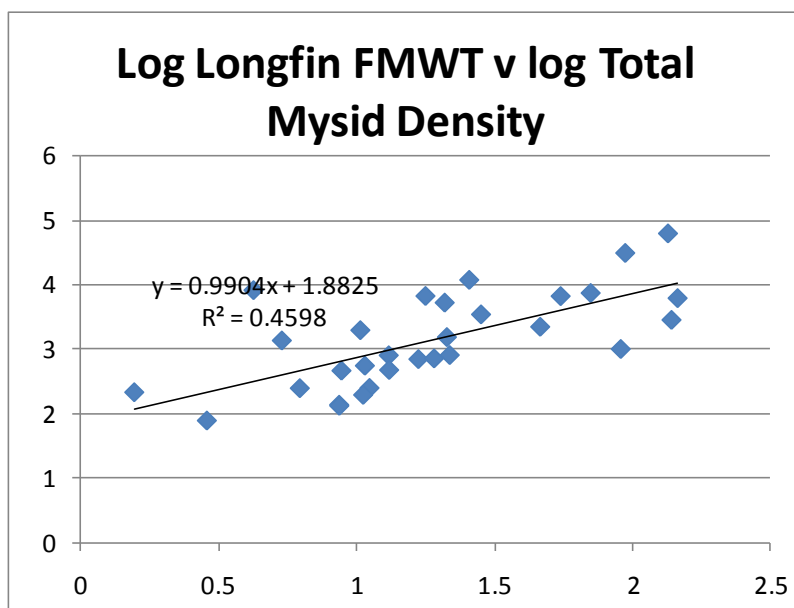


Fig. 3. Log (Longfin FMWT) v log (Total Mysid Density) in Suisun Bay 1975 - 2006

b. Published literature suggests that reduced food availability and not changes in outflow have been driving declines in longfin smelt abundance

DFG admits the biological basis for the residual spring outflow relationship is unknown, while nevertheless citing speculation by Baxter *et al.* (2009)¹² that the larvae benefit from increased downstream transport, increased food production, and reduction in entrainment losses at the export pumps.

In reaching this conclusion, there are numerous published works that DFG disregarded; sources pointing out the weakness of flow relationships with longfin smelt as well as identifying potential causes of declines, as follows:

- Rosenfield and Baxter (2007)¹³ identified food limitation as a causative factor in the decline of longfin smelt.

¹² Baxter R, Nobriga M, Slater S, Fujimura R. 2009. Effects Analysis. State Water Project effects on longfin smelt. California Department of Fish and Game, Sacramento, CA.

- Baxter *et al.* (2008)¹⁴ identified grazing by *C. amurensis* on prey as the cause of the post-1987 decline in longfin smelt, especially a summer food decline as a major stressor on age-0 longfin juveniles.
- Kimmerer *et al.* (2001)¹⁵ suggests a reduction in ecosystem carrying capacity related to changes in the food web as a reason for declines in YOY striped bass.
- Kimmerer *et al.* (2005)¹⁶ found evidence of a decades-long chronic food limitation as the cause of declines in *Acartia* spp. in the lower estuary.
- Sommer *et al.* (2007)¹⁷ noted that food web changes caused by *C. amurensis* grazing may be responsible for reduced fall recruitment in 2003-2005.
- Moyle (2002)¹⁸ speculated that the continuing decline of longfin smelt abundance is attributable to multiple factors acting synergistically - the impact of introduced species on longfin food supply, extreme flooding during spawning, impacts of introduced predators, and toxic substances as possible contributors.
- The Bay Institute in its petition to list longfin smelt (2007)¹⁹ cited outflow, entrainment, food-related impacts of invasive species, toxic pollutants, water temperature increases, and physical disruption of spawning habitat and critical prey species habitat by dredging.
- Glibert (2010)²⁰ performed CUSUM analyses on nutrient ratios and food web organisms and found a strong relationship between, among other things, declines in *E. affinis* and changing nutrient ratios.
- DFG (2009A)²¹ indicates that longfin smelt produced fewer young per unit of outflow after 1987 than they did previously, attributing this to *C. amurensis*.

The literature that DFG ignored, including its own, overwhelmingly indicates that an inadequate food supply, rather than outflow, is driving observed declines in longfin smelt abundance. While the DFG Report acknowledges the positive correlation between *E. affinis* abundance and spring outflow, citing Kimmerer (2002), Fig. 7,²² reproduced here as Figure 4, DFG improperly relies on this analysis to

¹³ Rosenfield J, Baxter. 2007. Population dynamics and distribution patterns of longfin smelt in the San Francisco estuary. *Transactions of American Fisheries Society* 136:1577-1592. Rosenfield and Baxter (2007) also plotted age-1 and age-2 average percent presence using the Bay Study and Suisun Marsh Survey data compared to average winter-spring outflow and found a positive but weak signal. The predictive power of the relationship was especially weak for age-2 (spawning) fish, which Rosenfield and Baxter pointed out could be explained by their anadromy.

¹⁴ Baxter R, Breuer R, Brown L, Chotkowshi M, Feyrer F, Gingas H, Herbold B, Mueller-Solger A, Nobriga M, Sommer T, Souza K. 2008. Pelagic organism decline progress report: 2007 synthesis of results, Interagency Ecological Program Report.

¹⁵ Kimmerer W, Cowan J, Miller L, Rose K. 2001. Analysis of an estuarine striped bass population: Effects of environmental conditions during early life. *Estuaries* 24:4, 557-575.

¹⁶ Kimmerer WJ, Ferm N, Nicolini MH, Penalva C. 2005. Chronic food limitation of egg production in populations of copepods of the genus *Acartia* in the San Francisco estuary. *Estuaries* 28:4, 541-560.

¹⁷ Sommer *et al.* (2007)

¹⁸ Moyle PB. 2002. Inland Fishes of California. Revised and Expanded. University of California Press. Berkeley.

¹⁹ Bay Institute. 2007. Petition to the State of California Fish and Game commission and supporting information for listing the longfin smelt (*Spirinchus thaleichthys*) as an endangered species under the California endangered species act. Submitted August 8, 2007.

²⁰ Glibert P. 2010. Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco Estuary, California. *Reviews in Fisheries Science* 18:2, 211-232.

²¹ California Department of Fish and Game. 2009A. A status review of the longfin smelt (*Spirinchus thaleichthys*) in California. Report to the Fish and Game Commission. 1/23/2009. Found at <http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=10263>.

²² Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series*, Vol 243: 39-55.

support its argument that additional spring outflow is necessary.²³ DFG reached its conclusion by misconstruing Kimmerer (2002).²⁴

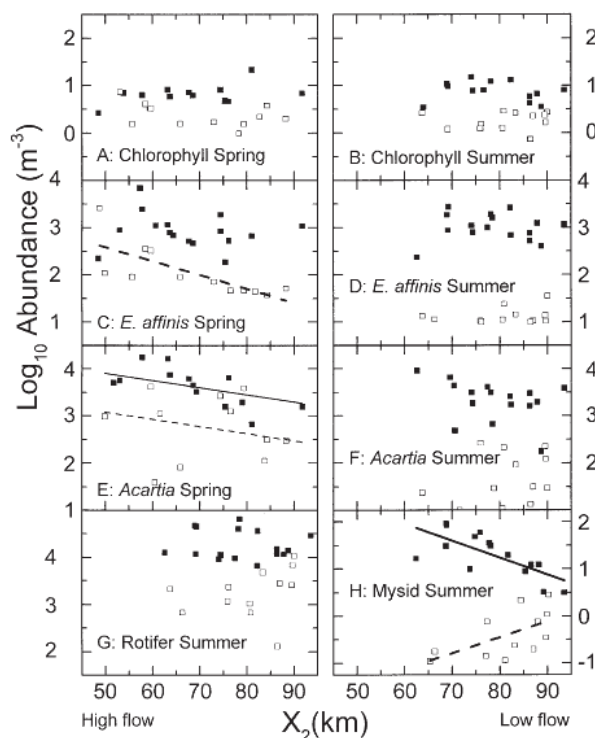


Figure 4 from Kimmerer (2002) Figure 7. Plankton abundance plotted against X_2 . Solid lines, data up to 1987; and dotted lines, 1988 to 1999.

Kimmerer (2002)²⁵ explained that potential causes of the above relationships could involve higher nutrient levels associated with higher flows (the agricultural model) or through stratification. However, the response of phytoplankton (chl-*a* concentration) has shown little response to freshwater flow either before or after *C. amurensis* became abundant (Fig. 4A, B). In the Delta, in spring, chl-*a* has actually decreased with increasing flow, apparently because of decreasing residence time (Jassby *et al.* 2002 in Kimmerer 2002).²⁶ Kimmerer (2002) further noted that without an increase in food supply with flow, there is no reason to expect any specific growth rate increase with increasing flow for any of the taxa shown in Figure 4 above. The food supply for zooplankton such as *E. affinis* is mostly phytoplankton (*i.e.*, diatoms). Yet increasing flows stifle phytoplankton growth. This conundrum offers little help in establishing spring outflow criterion, and certainly does not support DFG's flow recommendation.

c. The evidence does not support DFG's hypothesis that longfin smelt annual production is related to negative OMR flows/salvage at the SWP and CVP

The DFG Report suggests that longfin "annual production" is related to negative flows in Old and Middle Rivers.²⁷ Specifically, DFG concluded: "The population abundance of juvenile and adult longfin smelt is inversely related to the number of fish salvaged at the SWP and CVP facilities."²⁸

²³ DFG Report at p. 65.

²⁴ Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series*, Vol 243: 39-55.

²⁵ Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series*, Vol 243: 39-55.

²⁶ Jassby *et al.* 2002 in Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? *Marine Ecology Progress Series*, Vol 243: 39-55.

²⁷ DFG Report at p. 62.

²⁸ DFG Report at p. 64.

Correlations may exist, but there is no evidence of a cause and effect relationship. Many factors in the Bay-Delta system are correlated with each other. For instance, OMR flows are highly correlated with X2. Normalized salvage of longfin is also correlated with X2. Therefore, it is no surprise to find that salvage and OMR are weakly correlated with longfin abundance. The existence of these correlations in no way implies some sort of causal connection.

Given the vanishingly small level of longfin salvage that occurs in most years, such a relationship between salvage and species abundance is extremely unlikely. Indeed, had the DFG Report taken the trouble to correlate longfin abundance against X2 and either OMR or normalized salvage it would have found that OMR and salvage are statistically insignificant.

In considering the speculated flow effects on longfin smelt, much credence is given to the unpublished and un-peer reviewed analysis prepared by The Bay Institute and the Natural Resources Defense Council (“TBI/NRDC”), which allegedly link spring Delta outflows to total fish salvage.²⁹ The TBI/NRDC Figure 8 at p. 17³⁰ inappropriately related total annual entrainment with spring outflows. Spring outflows obviously cannot affect entrainment during other seasons. When March-May salvage is considered (corresponding with spring), the result is an exponential relationship with Delta outflow, with salvage approaching zero when outflow is greater than about 15,000 cfs and sometimes jumping to higher levels at lower outflow levels. (See Figure 5 below.) Existing flow patterns are nearly always adequate to surpass this outflow level. TBI/NRDC does not demonstrate that higher outflows are needed or that salvage is an important stressor on longfin smelt.

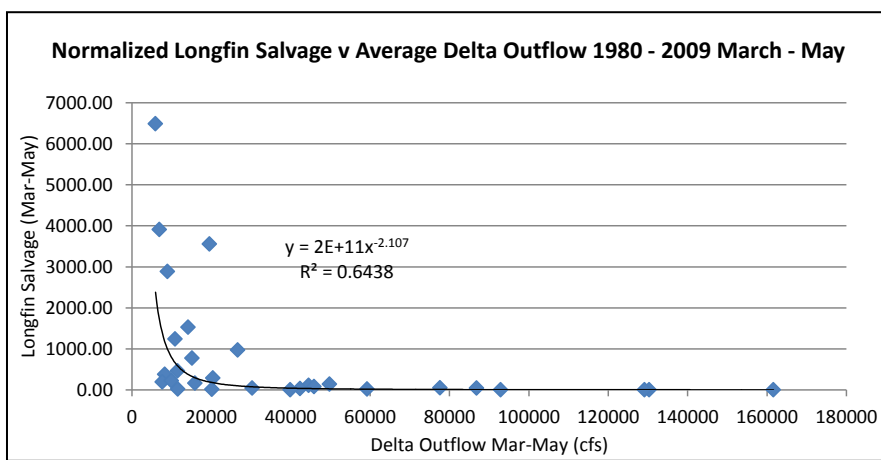


Figure 5. Longfin smelt salvage (March-May) as a function of Delta outflows (March-May). Outflows from DAYFLOW. Salvage normalized by dividing salvage by year 1 longfin CPUE from the Bay Study MWT during the preceding year.

TBI/NRDC’s Figure 11 claims a significant relationship between the FMWT Index of spawning-age longfin and total salvage of longfin smelt from 1993-2007, explaining that their negative correlation indicates that increases in salvage are not a result of increased abundance.³¹ The biological mechanism for the FMWT Index in one year being inversely related to salvage the next year is unapparent, as is its predictive power. SFCWA reanalyzed the relationship from 1981-2007 (excluding the year 2006 which had zero longfin salvage) and found a very strong relationship ($p < 0.001$) but with very weak predictive

²⁹ See, The Bay Institute and Natural Resources Defense Council (“TBI/NRDC”) Opening Statements, State Water Board Flow Proceedings, pp. 4 to 17.

³⁰ TBI/NRDC Opening Statements, State Water Board Flow Proceedings, Exh. TBI-2, Written Testimony of Jonathan Rosenfield, Ph.D and Christina Swanson, Ph.D Regarding Flow Criteria for the Delta Necessary to Protect Public Trust Resources: Delta Outflows, Fig.8, p. 17.

³¹ TBI/NRDC Opening Statements, State Water Board Flow Proceedings, Exh. TBI-4, Christina Swanson, PhD, regarding flow criteria for the Delta necessary to protect public trust resources, Delta hydrodynamics, Fig. 11, p. 20.

power ($R^2=0.09$) and a large range around the trend. (See Figure 6 below.) This indicates that no real conclusions can be drawn about long-term longfin salvage and abundance as measured by the FMWT.

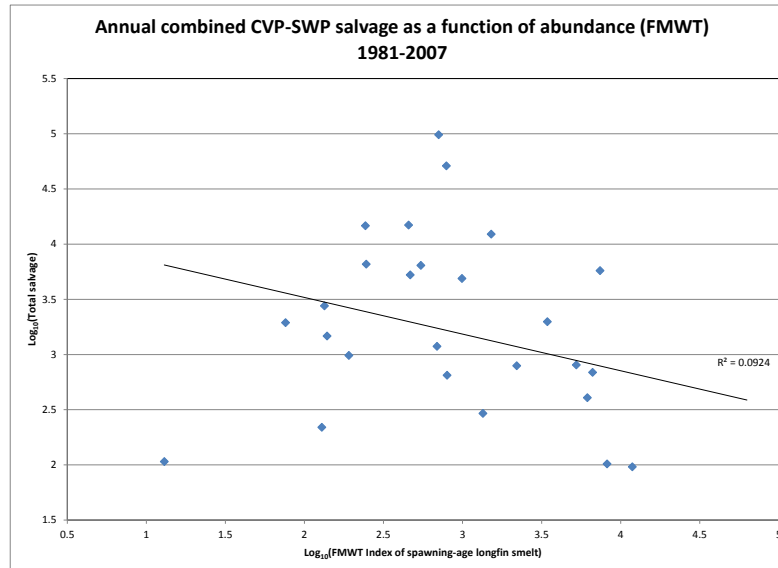


Figure 6. Total salvage as a function of abundance. CVP-SWP salvage from <http://www.dfg.ca.gov/delta/Data/Salvage/>. FMWT Index for longfin smelt from <http://www.dfg.ca.gov/delta/data/fmwt/charts.asp>.

If salvage was a significant factor affecting longfin population as expressed by the FMWT Index, the logical conclusion one would expect is that high relative entrainment would lead to a low FMWT Index. Figure 6 simply does not bear this out. In fact, an examination of longfin distribution shows that they are rarely in the zone of influence. The highest risk of entrainment for longfin smelt would occur if they were found in the lower San Joaquin River, near Franks Tract, in the southeast Delta, or the central Delta. Yet their distributions, both historically and at present, indicate they are infrequently found in these regions and, when found, are only in low numbers. (See Figure 7 below.)

In a further attempt to show that larval longfin smelt might be entrained in higher numbers, the DFG Report uses the Delta Simulation Model (DSM2, particle tracking module) to predict the fate of larval longfin smelt, as described in DFG (2009B).³² The results purportedly “might be substantial (2 to 10 percent)” during relatively low outflow conditions.³³ However, it is difficult to perceive how 90-98% of the particles were not entrained but that this is a “substantial” loss.

DFG (2009B) also cites Grimaldo *et al.* (2009)³⁴ and various patterns of entrainment to demonstrate that OMR reverse flows result in an exponential increase in salvage loss. Without understanding the effect on the population of the salvaged fish, the actual significance of the patterns in DFG (2009B) or Grimaldo *et al.* (2009) are not apparent, especially when considering Figure 6 above.

Baxter *et al.* (2009)³⁵ reached similar conclusions as Grimaldo *et al.* (2009) using a particle tracking model to predict the fate of larval longfin smelt. For PTM results to be valid, an assumption must be made that behaviorless particles adequately simulate larval fish, which is rarely the case. As well, the

³² California Department of Fish and Game. 2009B. State Water Project effects on longfin smelt.

³³ DFG Report at p. 65.

³⁴ California Department of Fish and Game. 2009B. State Water Project effects on longfin smelt, *citing*, Grimaldo L, Sommer T, Van Ark N, Jones G, Holland E, Moyle P, Herbold B. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? *North American Journal of Fisheries Management* 29:1253–1270.

³⁵ Baxter R, Nobriga M, Slater S, Fujimura R. 2009. Effects Analysis. State Water Project effects on longfin smelt. California Department of Fish and Game, Sacramento, CA.

insertion points must reflect the actual areas where fish are found. The insertion points used by Baxter *et al.* (2009) were Stations 716, 711, 704, 809, 812, 815, and 906, the latter four of which are located in the south and eastern Delta. Attachment B hereto demonstrates that longfin smelt are seldom in these regions in large numbers. Therefore, the results of Baxter *et al.* (2009) do not match the actual data.

The absence of longfin smelt in the south Delta surveys is, as one would expect, reflected in the exceedingly low salvage rates actually recorded at the SWP and CVP pumping facilities. Figure 7, lifted from the IEP Newsletter of Spring 2009,³⁶ shows annual salvage of longfin smelt at both the SWP and CVP fish facilities. Except for 2002, annual salvage has been extremely low for well over a decade. The data thus provide very clear evidence that SWP and CVP pumping operations are not a significant cause of the longfin smelt's decline in abundance.

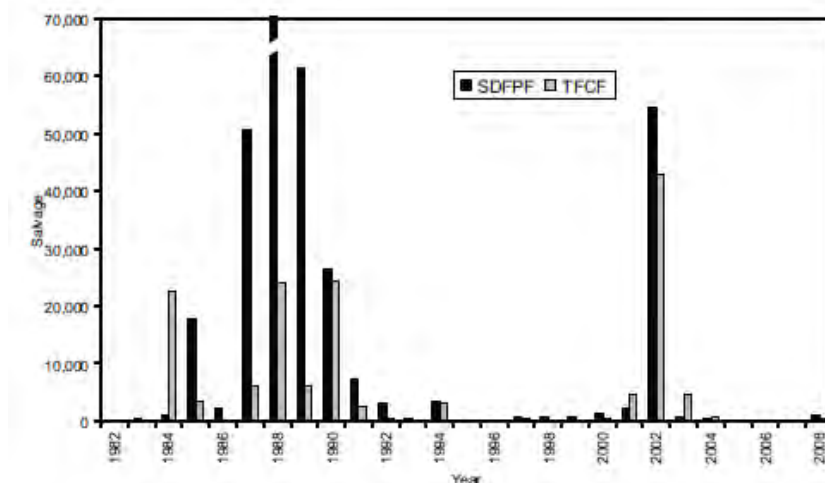


Figure 7. Annual salvage of longfin smelt at the Skinner Delta Fish Protection Facility and Tracy Fish Capture Facility, 1982-2008. Annual salvage for 1998 is truncated for scale considerations (140,040). From IEP Newsletter Spring 2009.

To further illustrate this lack of relationship, analysis of salvage data displayed in Figure 8, below, shows the relative change in longfin smelt abundance for each year between 1979 and 2008 versus the relative longfin smelt salvage for the corresponding year. In this figure, the relative change in longfin smelt abundance is plotted as a fraction comparing each year to the prior year. If there was no change in abundance from year to year, the value plotted is one. If there was an increase in abundance, the value plotted is greater than one. If there was a decrease, then the value plotted is less than one. This ratio of abundance from year to year is compared to the amount of entrainment, which is adjusted by the FMWT level the prior year to reflect relative entrainment impacts on population.

³⁶ Interagency Ecological Program for the San Francisco Estuary ("IEP") Newsletter, Spring 2009, Vol. 22, No. 2.

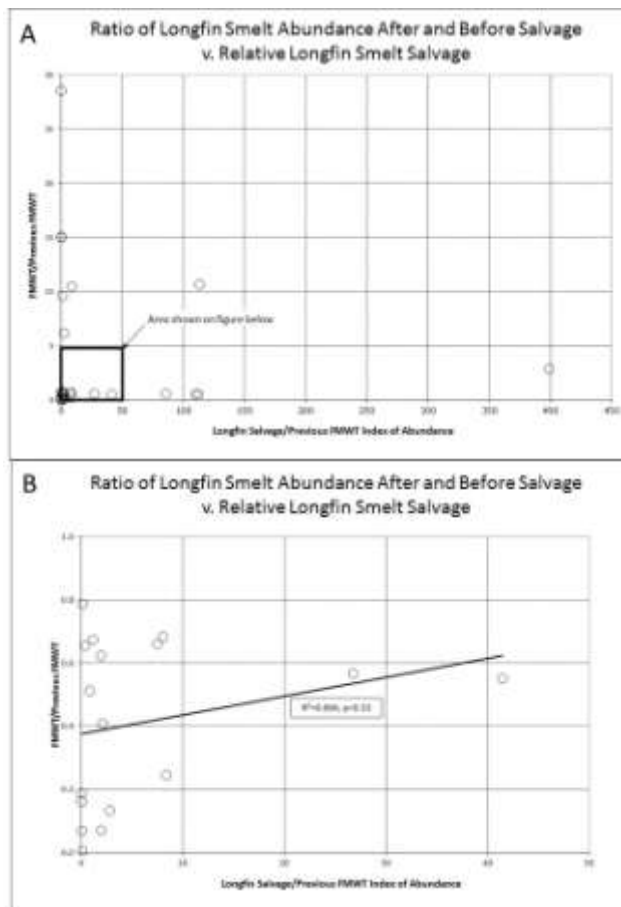


Figure 8. Ratio of longfin smelt abundance after and before salvage v. relative longfin smelt salvage. A. Data for 1981-2008. B. Blow-up of ratio < 1. The low coefficient of determination (R^2) and insignificance of the correlation ($p > 0.05$) indicates the lack of relationship between salvage and longfin smelt abundance as measured by the FMWT Index.

If entrainment was a significant factor affecting population, one would expect to find that high relative entrainment (on the horizontal axis) would cause a low population level impact (on the vertical axis). Figure 8A shows that there is no such relationship. The year with the highest level of salvage relative to FMWT, with 398, had a slight increase in subsequent year FMWT Index. Put another way, longfin smelt abundance, as measured by the FMWT Index, actually increased in the year following the highest relative entrainment. Conversely, several years with near-zero entrainment were followed by years with decreased longfin smelt FMWT indices. This effect shows up most clearly in a closer examination of the data near the origin, as displayed in Figure 8B. This figure shows many years when abundance declined were preceded by years in which there was virtually no salvage or none at all. The most recent example of this effect was in 2006, when there were no longfin smelt taken and the longfin smelt FMWT fell from 1949 to 13 (in 2007).

The DFG Report references the generation-over-generation analysis by TBI/NRDC which suggests higher spring flows lead to growing populations of longfin smelt.³⁷ In its Figure 13, TBI/NRDC subtracted the previous FMWT Index from the Bay Study Index to calculate its population change and correlated this with March-May Delta outflows in the latter cohort (Bay Study Index). In its Figure 14, TBI/NRDC subtracted the previous FMWT Index from the FMWT Index and correlated this with January-March

³⁷ DFG Report at p. 65; TBI/NRDC Opening Statements, State Water Board Flow Proceedings, Exh. TBI-2, Written Testimony of Jonathan Rosenfield, Ph.D and Christina Swanson, Ph.D Regarding Flow Criteria for the Delta Necessary to Protect Public Trust Resources: Delta Outflows, Fig. 13, p. 16.

Delta outflows in the latter cohort (FMWT Index).³⁸ TBI/NRDC also limited their analysis to post-1987 data because of a purported step decline in abundance after 1987.

The TBI/NRDC analysis is flawed in several ways. Since the Bay Study is age-structured, there is no reason to mix indices. Also, pre-1987 CPUE from the Bay Study does not show a step decline. TBI/NRDC's Figure 14 subtracted the previous FMWT Index from the FMWT Index and correlated this with January to March Delta outflows in the latter cohort (FMWT Index). Again, TBI/NRDC limited their analysis to post-1987. SFCWA re-plotted TBI/NRDC's Figure 13 using only the Bay Study data for age-0 and age-1 fish for 1981-2008, the full time period for the Bay Study. (See Figure 9A below). The results do not support TBI/NRDC's contention that higher flows lead to higher abundances. In fact, using the Bay Study data, higher flows are associated with declining abundances and lower flows are associated with increasing abundances. SFCWA also re-plotted TBI/NRDC's Figure 14 using 1981-2008 data. (See Figure 9B below.) The correlation between January-March outflows and population change as measured by the FMWT Index is highly insignificant with essentially no predictive power. No insights are gained with respect to the effect of spring flows on longfin smelt abundances using either the Bay Study or the FMWT datasets.

As has been shown, the TBI/NRDC statistical analysis that purported to show that longfin abundance has been significantly affected by entrainment in the water facilities is profoundly flawed. DFG should not have relied on it.

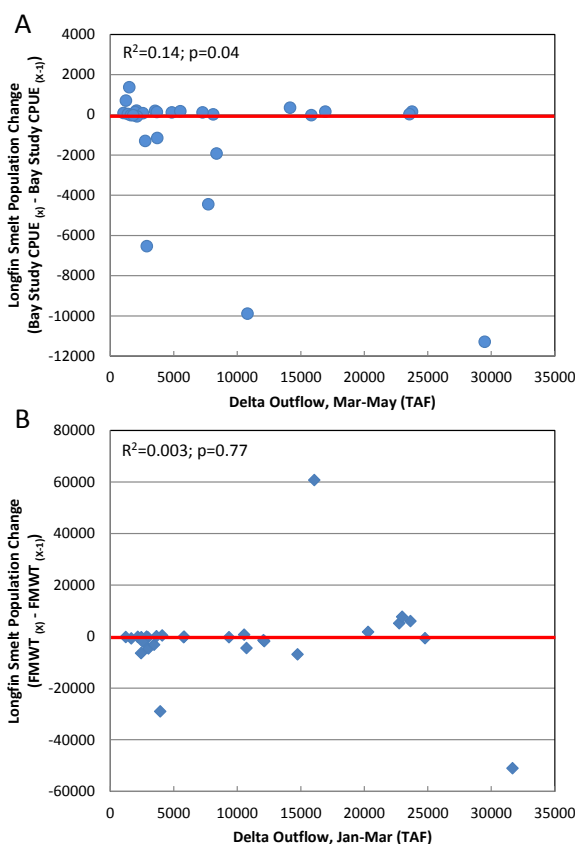


Figure 9. Generation-to-generation change in abundance for longfin smelt (1981-2008). A. March-May Delta outflow in the later cohort and Bay Study CPUE. Abundance data from Bay Study (<ftp://ftp.dfg.ca.gov/BayStudy/LongfinSmelt/>). B. January-March Delta outflow in the later cohort and FMWT Index. Abundance data from FMWT (<http://www.dfg.ca.gov/delta/data/fmwt/charts.asp>). Delta outflows from DAYFLOW. Horizontal lines divide growing populations from those that declined.

³⁸ *Ibid*, Figure 14.

VI. DFG failed to acknowledge the compelling science that establishes that new outflow criteria will not increase Delta smelt abundance

The DFG Report admits that, “Delta smelt abundance does not respond to freshwater outflow during springtime (Stevens and Miller 1983; Kimmerer 2002a).”³⁹ The DFG Report nevertheless attempts to find some relationship between outflow and abundance to rationalize the unrealistic outflow recommendation. DFG argues: (a) “Delta smelt distribution is influenced by outflow through its influence on the location of X2,” which results in increased entrainment in the project facilities; (b) “Although outflow did not positively affect Delta smelt abundance, outflow did have significant positive effects on several measures of delta smelt habitat [i.e., fall X2 hypothesis;]” and (c) “...spring outflow significantly increased spring abundance of *E. affinis* (Kimmerer 2002a), an important Delta smelt prey item.”⁴⁰

a. The fall X2 hypothesis is conceptually and technically flawed.

The Fall X2 hypothesis is conceptually and technically flawed for several reasons: (1) X2 is not an appropriate surrogate for delta smelt habitat, nor is it an especially strong predictor of delta smelt distribution; (2) X2 does not exhibit a strong, predictive relationship with delta smelt abundance; and (3) There is no empirical support for the hypothesis that changes in X2 are driving food web, species composition, and other stressor impacts.

1. The science does not support the conclusion that fall X2 is a useful surrogate for Delta smelt habitat, nor is it an especially strong predictor of Delta smelt distribution.

The assertion that the lens of X2 and its location in the estuary constitutes habitat for delta smelt, or can serve as a valid surrogate for delta smelt habitat, is not supported by available information. Delta smelt do inhabit the Delta’s low-salinity zone, where they have been recorded in estuary areas with salinities ranging from 0 to 16 ppt and more. Historically widespread in the Delta, the smelt is now largely restricted to its more northern sub-areas of its historical distribution, from Suisun Bay east up into the mainstem Sacramento River, with highest densities around Liberty Island, Cache Slough, and the Sacramento Ship Channel. The low salinity zone occupies that and much of the historical area of Delta smelt occupancy, and areas that appear to be currently more densely populated by Delta smelt frequently experience low salinity conditions. But X2 neither defines Delta smelt habitat, nor is it a valid surrogate for the actual habitat required by Delta smelt.

Jassby et al. (1995)⁴¹ recognized the X2 zone as having “simple and significant statistical relationships with many estuarine resources,” but explicitly noted that they could not find a “statistically verifiable relationship” between delta smelt *E. affinis* and X2. In their investigation of pelagic organisms, Kimmerer et al. (2009)⁴² found that just two of eight species associated with the low salinity zone exhibited population responses that suggest the volume of those waters is a measure of habitat quality. The Delta smelt was not one of those species. Feyrer et al. (2007),⁴³ in a study that asserted that a relationship between “fall stock abundance” of Delta smelt and “water quality” was contributing to the decline in the species, advanced the idea that X2 was a surrogate for Delta smelt habitat, which could also predict Delta smelt abundance.

³⁹ DFG Report at p. 70.

⁴⁰ *Ibid.*

⁴¹ Jassby, Alan D, et al. 1995. Isohaline Positions as a Habitat Indicator for Estuarine Populations, *Ecological Application*, 5(1), pp. 272-289.

⁴² Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuaries and Coasts* 32:375-389.

⁴³ Feyrer, Fredrick, Nobriga, Matthew, and Sommer, Ted R. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. *Can. J. Fish. Aquatic Sci.* 64:723-734.

Feyrer's analysis contains a flawed concept of habitat. The habitat of a species includes the geographic areas it occupies and the resources it uses. Those resources include both physical resources and biotic resources; combined they provide the environmental elements necessary for the survival, persistence, and recovery of an imperiled organism. Habitat is a species-specific concept; no two organisms exhibit identical habitat requirements, because no two organisms use identical resources and require the same environmental conditions. Vegetation communities, like mixed-conifer forests, or aquatic zones with unique physical conditions, such as the brackish waters of estuaries, are often referred to as habitats. They are not habitats. They do, however, provide some or even all of the essential resources necessary to support specific species, and the habitat requirements of those same species may be met in part or in total in those forests or waters with their distinctive characteristics. Few species have all of their resource needs met in a single community or ecosystem type; fewer species still occupy the full extent of a community or ecosystem. Hence the concept of habitat is not co-equal to that of community, ecosystem, or land-cover type.

Habitat frequently includes areas that are suitable for a given species, but may not be occupied at a given time, as the presence or abundance of the species will vary dynamically in response to habitat condition or quality. Habitat quality is often inferred from the density of the targeted species, with areas supporting higher densities usually considered to be higher in habitat quality. But habitat quality should be inferred from data on fitness; the highest quality habitats are those that contribute to population persistence by maximizing species survival over mortality through time. The best habitat areas support stable or growing populations, not necessarily the highest densities of individuals at any given time. Because of the frequent discordance between habitat conditions and occupancy of or population density in an area of habitat, care must be taken when drawing conclusions regarding the resources and resource conditions that are necessary to assure the persistence of any target species.

The DFG Report is premised on an incorrect definition of Delta smelt habitat, an inappropriate interpretation of habitat in the context of resource management, and associated management prescriptions that, based on the most reliable information, are unlikely to produce any affirmative responses in the declining Delta smelt population. In light of emerging evidence that the disruption of the food web that supports the Delta smelt and depredation of the species by multiple non-native predatory fishes may be better predictors of the decline of Delta smelt than any one abiotic factor or any combination of abiotic factors that are now impacting the estuary, it appears that managing for a specific (downstream) position for X2 will have no positive impact on delta smelt.

2. X2 does not exhibit a strong, predictive relationship with Delta smelt abundance; and the Feyrer *et al.* studies relied upon for the contrary proposition are fatally flawed.

Feyrer *et al.* (2007)⁴⁴ provides the sole scientific support for the notion that a supposed upstream shift in Fall X2 has constricted available Delta smelt habitat and caused population declines in the species. Feyrer *et al.* is conceptually flawed, describing a relationship between Delta smelt and three physical attributes of the Delta ecosystem. Instead of acknowledging that those three abiotic parameters constitute just a few of the attributes that contribute to the complex, multidimensional habitat space that supports Delta smelt, Feyrer *et al.* defines the combination of salinity, turbidity, and temperature as "abiotic habitat" for Delta smelt. The authors conclude that of those three habitat variables, which collectively explain only 25.7% of the variance in distribution of Delta smelt, X2 was best correlated with Delta smelt abundance based on a correlation they detected between X2 and distribution using FMWT data.

The Feyrer *et al.* analysis is technically flawed. They use a linear additive model, which is biologically implausible and inappropriate, that is, it generates biologically implausible results, like obtaining stock from zero spawners, since additive terms are used, and it treats environmental variables as having a fixed, rather than a proportionate effect. Investigating the Fall X2-abundance relationship with a multiplicative

⁴⁴ Feyrer, Fredrick, Nobriga, Matthew, and Sommer, Ted R. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. *Can. J. Fish. Aquatic. Sci.* 64:723-734.

model instead of a linear additive one is superior, as Feyrer has conceded when testifying under oath.⁴⁵ Analyzing Feyrer *et al.*'s data with a multiplicative model (specifically, a Ricker stock-recruit model) shows that there is no statistically significant relationship between Fall X2 and subsequent Summer Townet-derived delta smelt abundance.

Dr. Richard Deriso has completed this analysis, analyzing the same data regarding abundance and Fall X2 that Feyrer used but with a scientifically-appropriate Ricker stock recruit model. Dr. Deriso found no statistically-significant relationship between Fall X2 and subsequent abundance.⁴⁶ Dr. Bryan Manly, using regression analyses, also independently concluded that Fall X2 added nothing to the stock recruit relationship between the FMWT abundance and STN abundance, stating:

Regression analyses ... showed that the fit of the regression line using Fall Midwater Trawl data alone was better at predicting the recent low summer townet levels than a regression using both Fall Midwater Trawl and X2. Put another way, adding X2 as a variable worsens the prediction of the recent summer abundance as compared to a simple stock-recruitment relationship. (Manly Decl. Doc. 347, p. 6. (Emphasis added).)⁴⁷

Feyrer's Fall X2 analysis is incomplete because it only investigated the stock recruit relationship in a portion of the life cycle, i.e., that between pre-adults (FMWT) →juveniles (STN). A Fall X2 analysis should include an examination of the stock recruit relationship throughout the entire life cycle. Dr. Deriso did that analysis using a Ricker model, and found that there was no statistically significant effect of Fall X2 on the population growth rate. As the distance of Fall X2 increased and shifted upstream, the growth rate varied randomly. (See e.g., Deriso Decl., Doc. 396, pp. 33-34 ["[T]his means that Fall X2 does not have a statistically significant effect on population abundance in a given year (adults to juveniles), or on the full life-cycle of the delta smelt (adults to adults)."].)⁴⁸

The National Research Council's ("NRC") 2010 report criticized Feyrer *et al.*'s Fall X2 analysis, noting that "the weak statistical relationship between the location of X2 and the size of the smelt population makes the justification for this action [the fall X2 requirement in the Delta smelt BiOp] difficult to understand"⁴⁹ The NRC Report also noted that Feyrer *et al.*'s analysis was based on a series of linked statistical analyses where "[e]ach step of the logic train of relationships is uncertain" and where "substantial variance [is] left unexplained at each stage."⁵⁰

The Fall X2 approach should be abandoned as other habitat characteristics and variables, like prey density, have much stronger relationships with abundance than Fall X2. Furthermore, whereas use of X2 as a surrogate for the suite of physical and biotic elements that constitute habitat is superficially parsimonious, a more robust surrogate that is derived by first assessing elements that directly affect the survival of the species, thereafter assessing elements that indirectly affect survival, then evaluating the combination of such elements most likely to represent habitat quality is preferable. The NRC

⁴⁵ Feyrer testified as follows:

Q. Let me put it another way. Wouldn't it be more appropriate to use a multiplicative model, in other words, a model that relates and deals with proportions rather than an additive model? If you're trying to determine the effect on the smelt population?

A. Multiplicative model would have been a better way of doing that relationship, yes.

In re Delta Smelt Cases, No. 09-CV-409; *In re Salmonid Cases*, No. 09-CV-1053 (USDC, E.D.Cal) (Emphasis added), Tr. at 1028:18-24, April 5, 2010 Hearing,

⁴⁶ The Consolidated Delta Smelt Cases, Case No. 1:09-cv-0407-OWW-GSA, Declaration of Richard Deriso, Doc. No. 401-1, pp. 31-33.

⁴⁷ The Consolidated Delta Smelt Cases, Case No. 1:09-cv-0407-OWW-GSA, Dr. Bryan Manly Declaration, Doc. No. 347, p. 6. (Emphasis added).)

⁴⁸ The Consolidated Delta Smelt Cases, Case No. 1:09-cv-0407-OWW-GSA, Declaration of Richard Deriso, Doc. No. 396, pp. 33-34.

⁴⁹ A Scientific Assessment of Alternatives for Reducing Management Effects on Threatened and Endangered Fishes in California's Bay-Delta. 2010. National Research Council ("NRC"), pp. 4, 40-41, <http://www.nap.edu/catalog/12881.html>

⁵⁰ *Ibid.*

Committee's report noted that because no study has shown that project operations are either the sole or most important effect on Delta smelt population dynamics, "the multiple other stressors that are affecting fish in the delta environment ... must be considered, as well as their comparative importance" (NRC 2010, p. 33).⁵¹ Feyrer *et al.* (2007) suggested that future analyses of Delta smelt habitat might be improved by including biotic variables, particularly food availability. However, before Fall X2 is deemed to be an indicator of Delta smelt habitat, an assessment must be made, using life-cycle modeling, of the comparative importance of other variables, which current scientific information shows have a more powerful effect on Delta smelt abundance than Fall X2.

In fact, the DFG Report recommends the use of a life-cycle model, although it fails to acknowledge that such a tool exists.⁵² Drs. Richard Deriso and Mark Maunder have developed such a model, which is being finalized and a manuscript prepared for publication. A second multivariate statistical analysis of factors influencing Delta smelt populations has also been done by Dr. Bryan Manly and others, covering all life stages of Delta smelt. A manuscript for publication is also being prepared for this analysis. These tools should be used to replace the Feyrer *et al.* approach in the DFG Report. Because Feyrer *et al.*'s investigation is limited to the effects of X2 on just one life stage, instead of throughout the complete life cycle (as would occur with a life-cycle model), its method cannot reliably evaluate the overall population-level effects of changes in Fall X2. Indeed, it is precisely because a life-cycle model can integrate effects at one life stage over all stages, taking into consideration density dependent effects at different stages, that it is universally recognized as a superior analytical tool. There was agreement among the scientists testifying in the litigation concerning the biological opinions on the continued operations of the CVP and SWP and the court-appointed experts retained by Judge Wanger, and a standing NRC Committee (2010, pp. 25-26), that a life-cycle model represents the "best available science" for investigating the effect of various factors and stressors on the Delta smelt population. Therefore, life-cycle modeling of Fall X2 (and of other habitat variables that may affect Delta smelt population dynamics) must be conducted to inform the DFG Report. If this tool is not used, despite the recognition that it constitutes the best available science under the ESA for investigating population-level effects, then the scientific credibility of the process by which the DFG Report was developed must be questioned.

3. There is no empirical support for the hypothesis that changes in X2 are driving food web, species composition, and other stressor impacts.

The DFG Report finds that the location of X2 and outflow indirectly affect Delta smelt habitat and population dynamics by encouraging growth of submerged aquatic vegetation and proliferation of *Microcystis* and by favoring invasive species over natives lacks empirical support.⁵³ The contention is supported by speculative hypotheses about the relationship between X2/outflow and species composition and the food web. Claims that project operations have been exacerbating third-party stressor impacts lack any identifiable support in the available scientific data. Moyle *et al.* (2010, p.20)⁵⁴ also lacks any empirical evidence for the hypotheses offered therein about effects caused by changes in habitat "variability" and "complexity," and the article itself acknowledges that its discussion consists of "speculative" findings. In contrast, Glibert (2010)⁵⁵ using empirical data finds that N:P ratios rather than hydrologic variables are driving changes in the Delta food web and species composition. Thus, a suggestion that reductions in outflow may exacerbate the impact of other stressors lacks any empirical support.

⁵¹ *Ibid.*

⁵² DFG Report at p. 77.

⁵³ DFG Report at pp. 31-33.

⁵⁴ Moyle, Peter B, *et. al.* 2010. Habitat Variability and Complexity in the Upper San Francisco Estuary. *Delta Solutions*. <http://deltasolutions.ucdavis.edu>.

⁵⁵ Glibert P. *In press*. Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco estuary, California. *Reviews in Fisheries Science*.

4. Increased spring outflow would have no effect on rate of entrainment

After admitting that no statistical relationships have been found between spring outflow and Delta smelt population abundance, the DFG Report discusses Grimaldo *et al.* (2009)⁵⁶ which argues that such a relationship does exist.⁵⁷ However, the DFG Report fails to discuss Rose *et al.* (2008),⁵⁸ which notes that Grimaldo *et al.* (2009) used in the USFWS BiOp should have normalized the salvage for population size (Rose *et al.* 2008 at p. 6).⁵⁹ This is a fundamental error that compromises the validity of Grimaldo *et al.*'s conclusions. Since Grimaldo *et al.* (2009) failed to consider population size, it is of little use for establishing Delta smelt flow criteria.

The DFG Report further accepts the Grimaldo *et al.* (2009) conclusion that minimizing reverse OMR flows during periods when adult delta smelt are migrating into the Delta could substantially reduce mortality. An evaluation of the distribution of Delta smelt based on the Kodiak Trawl, which targets spawning Delta smelt, does not bear this out. Table 1 lists the Kodiak Trawl distributions of adult Delta smelt from 2002-2008. For fish to be entrained, they must be located in the southern or eastern portion of the Delta where the export projects are located.

Table 1. Distribution of adult delta smelt based on Kodiak Trawl data, 2002-2008. Data from <http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SKT>.

year	survey	survey mid-date	Napa River	Car-quinez Strait	Suisun Bay	Chippis Island	lower Sacramento River	lower San Joaquin River	Suisun Marsh	Cache Slough	Sacramento Ship Channel	upper Sacramento River	near Franks Tract	south-east Delta	east south-east Delta	east central Delta	sum for SE & E-SE Delta
2002	1	8-Jan	0%	5%	11%	6%	3%	19%	30%	1%		0%	21%	3%	0%	1%	4%
2002	2	5-Feb	0%	2%	3%	0%	7%	18%	47%	0%		1%	22%	0%	0%	0%	0%
2002	3	5-Mar	1%	0%	2%	0%	42%	2%	32%	12%		0%	6%	0%	3%	2%	3%
2003	1	19-Feb	0%	0%	27%	16%	8%	4%	14%	20%		0%	7%	1%	2%	0%	3%
2003	2	18-Mar	0%	0%	21%	10%	40%	0%	5%	16%		4%	2%	0%	0%	2%	0%
2003	3	15-Apr	0%	0%	5%	0%	33%	2%	0%	3%		8%	49%	0%	0%	0%	0%
2003	4	14-May	0%	0%	62%	0%	10%	8%	0%	18%		0%	0%	0%	0%	3%	0%
2004	1	13-Jan	1%	0%	1%	4%	0%	21%	35%	0%		0%	29%	1%	7%	0%	8%
2004	2	13-Feb	0%	0%	2%	1%	36%	8%	29%	0%		0%	23%	0%	0%	0%	0%
2004	3	10-Mar	0%	0%	14%	5%	20%	2%	22%	0%		0%	35%	0%	1%	1%	1%
2004	4	6-Apr	0%	0%	3%	1%	45%	7%	0%	1%		2%	40%	0%	0%	0%	0%
2004	5	5-May	0%	0%	0%	0%	23%	40%	0%	5%		0%	33%	0%	0%	0%	0%
2005	1	26-Jan	0%	0%	24%	7%	34%	0%	23%	3%		0%	9%	0%	0%	0%	0%
2005	2	24-Feb	6%	0%	5%	4%	16%	1%	60%	7%	1%	0%	0%	0%	0%	0%	0%
2005	3	24-Mar	0%	0%	9%	19%	32%	0%	8%	8%	19%	5%	0%	0%	0%	0%	0%
2005	4	19-Apr	0%	0%	11%	8%	33%	0%	3%	5%	39%	0%	0%	0%	0%	0%	0%
2006	1	18-Jan	26%	9%	12%	7%	0%	8%	26%	2%	7%	0%	5%	0%	0%	0%	0%
2006	2	15-Feb	24%	4%	32%	5%	2%	2%	14%	3%	8%	0%	4%	2%	0%	1%	2%
2006	3	15-Mar	31%	0%	10%	9%	3%	0%	3%	4%	32%	0%	6%	0%	0%	0%	0%
2006	4	12-Apr	5%	0%	0%	2%	4%	3%	1%	0%	80%	0%	6%	0%	0%	1%	0%
2006	5	9-May	0%	0%	39%	39%	0%	13%	0%	3%	0%	0%	0%	0%	0%	6%	0%
2007	1	9-Jan	0%	0%	0%	21%	31%	5%	25%	3%	6%	0%	10%	0%	0%	0%	0%
2007	2	7-Feb		0%	0%	17%	34%	0%	6%	0%	43%	0%	0%	0%	0%	0%	0%
2007	3	8-Mar	0%	0%	6%	18%	11%	0%	29%	2%	34%	0%	0%	0%	0%	0%	0%
2007	4	4-Apr	0%	0%	0%	3%	9%	0%	2%	0%	86%	0%	0%	0%	0%	0%	0%
2007	5	2-May	0%	0%	0%	0%	10%	0%	3%	0%	87%	0%	0%	0%	0%	0%	0%
2008	1	9-Jan	0%	2%	11%	7%	58%	0%	1%	1%	19%	0%	1%	0%	0%	0%	0%
2008	2	6-Feb		0%	0%	8%	4%	0%	0%	5%	77%	0%	4%	0%	0%	1%	0%
2008	3	12-Mar	0%	0%	0%	3%	5%	0%	3%	1%	82%	0%	6%	0%	0%	0%	0%
2008	4	9-Apr	0%	0%	0%	0%	39%	0%	0%	0%	61%	0%	0%	0%	0%	0%	0%
2008	5	7-May	0%	0%	0%	0%	26%	0%	0%	3%	71%	0%	0%	0%	0%	0%	0%
avg.			3%	1%	10%	7%	20%	5%	14%	4%	24%	1%	10%	0%	0%	1%	1%

As illustrated by Table 1, Delta smelt are seldom found in these regions, suggesting that they are seldom at risk of entrainment by reverse OMR flows.

The best available science does not support the notion that entrainment at the SWP/CVP export facilities have a significant population level impact on Delta smelt. The effects analysis done as part of the Delta

⁵⁶ Grimaldo L, Sommer T, Van Ark N, Jones G, Holland E, Moyle P, Herbold B. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? *North American Journal of Fisheries Management* 29:1253-1270.

⁵⁷ DFG Report at p. 70.

⁵⁸ Rose K, Kimmerer W, Leidy G, Durand J. 2008. Independent peer review of USFWS's final effects analysis for the operations criteria and Plan's biological opinion. United States Fish and Wildlife Service.

⁵⁹ *Id* at p. 6.

smelt BiOp states: "Currently published analyses of long-term associations between delta smelt salvage and subsequent abundance do not support the hypothesis that entrainment is driving population dynamics year in and year out (Bennett 2005; Manly and Chotkowski 2006; Kimmerer 2008)."⁶⁰ This one statement summarizes the state of knowledge about population level effects of entrainment. Use of OMR flow restrictions aimed at improving Delta smelt populations is unsupported by the available science and should be deleted from the DFG Report.

5. The science does not support the conclusion that Delta smelt require additional outflow to support migration

The DFG Report accepts the hypothesis that Delta smelt undergo an annual upstream migration to spawn, triggered by first flush turbidity events or Sacramento River flows in excess of 25,000 cfs.⁶¹

The actual monitoring data tells a different story, revealing a year-round, non-migrating sub-population in the west Delta and Liberty Island region of Cache Slough (Nobriga *et al.* 2005; Sommer *et al.* 2009).⁶² These regions are similar to the historical habitat conditions that existed in the Bay-Delta prior to its reclamation into agricultural lands and flood control corridors. Catch of Delta smelt in these regions is thought to be a substantial portion of the population; ~42% of the Spring Kodiak Trawl catch during March-May since 2005 has been in the Cache Slough complex (Sommer *et al.* 2009).⁶³ Therefore, establishment of flow criteria specific to migration of Delta smelt from or to the south Delta ignores the accumulating data that a large portion may not migrate at all. In fact, with such a substantial portion of the population spawning, rearing, and maturing in the west Delta and Cache Slough regions, it is not known whether high south Delta flows to elicit migration may in fact inhibit their reaching these upstream regions.

Moreover, as Delta smelt prefer turbid conditions, it would be a mistake not to consider turbidity in any proposal regarding smelt migration. Turbidity in the Bay-Delta is not a function of flows, *per se*, but rather a function of storm activity that induces erosion (Wright and Schoellhamer 2004).⁶⁴ In fact, sediment loads have been dropping for the Sacramento River. Grimaldo *et al.* (2009)⁶⁵ evaluated whether salvage followed first flush precipitation events. Such first flush events are not typically long-lasting. Therefore, recommendation of a specific flow as a migration trigger without considering turbidity is not supported by the best available science and could result in large flows without biological benefit for Delta smelt because these are not necessarily related to turbidity.

VII. DFG misinterprets, or fails to provide, the scientific studies and research required to support its flow proposal for salmonids

DFG misinterprets and misapplies the scientific research that it cites. As a result, its conclusion is without a strong scientific foundation and therefore cannot be used in agency decision-making.

a. DFG's assertion that high Sacramento River inflows are needed to prevent "reverse flows" harmful to juvenile salmonids is not scientifically justified.

⁶⁰ USFWS. 2008. Formal Consultation on the coordinated operations of the Central Valley Project and the State Water Project ("Delta smelt BiOp"), p. 210.

⁶¹ DFG Report at p. 74.

⁶² Nobriga M, Feyrer F, Baxter R, Chotkowski M. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass. *Estuaries* 28:776-785; Sommer T, Reece K, Mejia F, Nobriga M. 2009. Delta smelt life-history contingents: A possible upstream rearing strategy? *IEP Newsletter* 22:1, 11-13.

⁶³ Sommer T, Reece K, Mejia F, Nobriga M. 2009. Delta smelt life-history contingents: A possible upstream rearing strategy? *IEP Newsletter* 22:1, 11-13.

⁶⁴ Wright S, Schollhamer D. 2004. Trends in the sediment yield of the Sacramento River, CA, 1957-2001. *San Francisco Estuary and Watershed Science* [online serial] 2:2, Art. 2.

⁶⁵ Grimaldo L, Sommer T, Van Ark N, Jones G, Holland E, Moyle P, Herbold B. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? *North American Journal of Fisheries Management* 29:1253-1270.

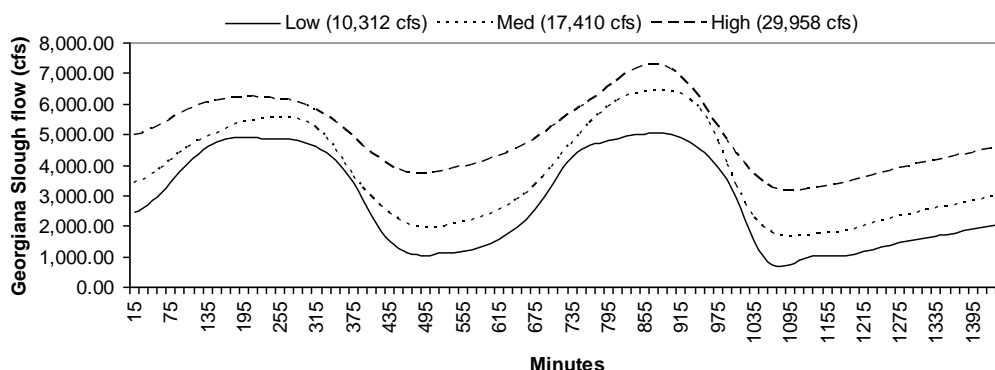
In describing Sacramento River inflows needed for juvenile salmonids, the DFG Report states:

Recent studies and modeling efforts have found that increasing Sacramento River flow such that tidal reversal does not occur in the vicinity of Georgiana Slough and at the Cross Channel Gates would lessen the proportion of fish diverted into channels off the mainstem Sacramento River (Perry et al. 2008, 2009). Thus, closing the Delta Cross Channel and increasing the flow on the Sacramento River to levels where there is no upstream flow from the Sacramento River entering Georgiana Slough on the flood tide during the juvenile salmon migration period (November to June) will likely reduce the number of fish that enter the interior Delta and improve survival. (DOI 1 as cited in SWRCB 2010). To achieve no bidirectional flow in the mainstream Sacramento River near Georgiana Slough, flow levels of 13,000 (personal communication Del Rosario) to 17,000 cfs at Freeport are needed (SWRCB 2010).⁶⁶

This conclusion in the DFG Report is problematic for three reasons. First, the cited studies (Perry *et al.* 2008, 2009) do not support or even address the claim that increasing Sacramento River flows reduce tidal reversals in the stated areas.⁶⁷ Rather, Perry *et al.* (2008, 2009)⁶⁸ describes behavior and survival of acoustically tagged juvenile salmonids. Nowhere do these papers evaluate or describe Sacramento River flows necessary to prevent tidal reversal.

Second, the other source for this claim of Sacramento River inflows necessary to prevent tidal reversals at the DCC and Georgiana Slough is a personal communication with Del Rosario (DOI Exh.1 at p. 24).⁶⁹ However, DOI does not provide any data or citation to support this claim.

Third, in contrast to the faulty (or absent) citations provided in the report, detailed hydrodynamic data and modeling tools are available to assess the occurrence of tidal reversal and to assess flows necessary (if any) to prevent such events. The DSM2 Hydro simulation model is one such example. Though a thorough hydrodynamic model based simulation evaluation is beyond the scope of this review, a cursory analysis illustrates that reverse flows do not occur in Georgiana Slough for Sacramento River flows at least as low as 10,312 cfs (Figure 10). Though tides do cause flows to wax and wane, flows in Georgiana Slough never go negative or reverse within the range of Sacramento River inflows considered by Kimmerer and Nobriga (2008).⁷⁰



⁶⁶ DFG Report at p. 44.

⁶⁷ *Ibid.*

⁶⁸ Perry, Russell W and Skalski, John R. 2008. Migration and Survival Route Probabilities of Juvenile Chinook Salmon in the Sacramento- San Joaquin River Delta during the Winter of 2006-2007, Final Report Submitted to FWS, Stockton Ca.; Perry, Russell W and Skalski, John R. 2009. Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento- San Joaquin River Delta during the Winter of 2007-2008, Final Report Submitted to FWS, Stockton Ca.

⁶⁹ Department of the Interior, Opening Statements in SWRCB Flow Proceedings, Exh. 1, p. 24.

⁷⁰ Kimmerer, Wim J and Nobriga, Matthew L. 2008. Investigating Particle Transport in the Sacramento- San Joaquin Delta Using a Particle tracking Model. *San Francisco Estuary and Watershed Science*. Vol. 6, Issue 1, Art. 4.

Figure 10. Sacramento River flow effect on tidal flux. Flows predicted by DSM2 Hydro (15 minute increments) for Georgiana Slough at three different levels of Sacramento River inflows (Low, Medium, High) with the Delta Cross Channel closed. Based on DSM2 Hydro data from Kimmerer and Nobriga (2008). See Kimmerer and Nobriga (2008) for a description of assumptions for physical modeling.

DSM2 Hydro simulations do indicate that Sacramento River flows influence the proportion of Sacramento River water entering Georgiana Slough (Figure 11), but the effect is rather subtle and does not approach the dramatic flow reversals cited in the Report. As discussed by Kimmerer and Nobriga (2008), closure of the Delta Cross Channel gates also has a dramatic influence on flows into Georgiana Slough. Closing the DCC gates increases flows into Georgiana by as much as 32% and thus acts to reduce benefits which might be achieved by increasing Sacramento River flows.

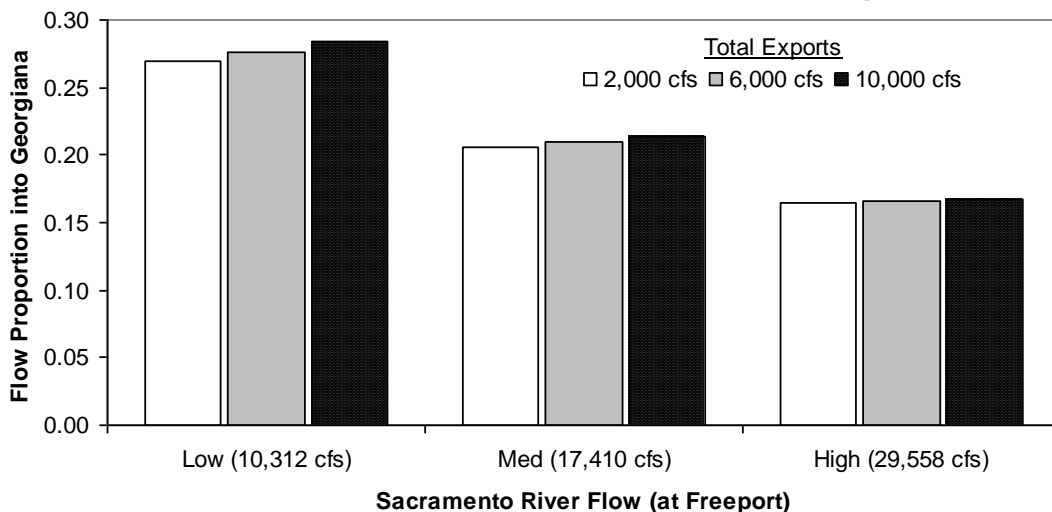


Figure 11. Proportion of Sacramento River entering Georgiana Slough as a function of Sacramento River inflows and exports. Based on DSM2 Hydro data from Kimmerer and Nobriga (2008). See Kimmerer and Nobriga (2008) for a description of assumptions for physical modeling.

In describing its flow recommendations, the DFG Report concludes: “To achieve no bidirectional flow in the mainstem Sacramento River near Georgiana Slough, flow levels of 13,000 (SWRCB 2010) to 17,000 cfs at Freeport are needed.”⁷¹ However, Figures 10 and 11 above show that Sacramento River flows cannot “prevent” salmonids from entering Georgiana Slough.

The “reversal” event referred to in the Report and related citations are not reverse flows such as occur in Old and Middle River as a result of exports. Rather, it is likely a transitory event occurring on some flood tides when the Sacramento River stage gets ahead of river stage on Georgiana Slough. The result is that flows into Georgiana Slough will be higher until the tidal stage equalizes. However, this event is not a reverse flow in the sense used elsewhere in the report. The duration and biological significance of the flood tide stage balancing at Georgiana Slough is uncertain. Given this uncertainty, flood tide stage balancing should be the subject of detailed hydrodynamic and biological assessment, not personal communications and unpublished papers, if it is to be used as a justification for increasing Sacramento River flows. Operations of the DCC should also be considered as part of any assessment for factors influencing flows and entrainment risk at Georgiana Slough.

b. DFG selectively used rotary screw trap data unadjusted for trap-efficiency to support high Sacramento River flows in the fall

In describing fall Sacramento River inflows needed for juvenile salmonids, the DFG Report states:

Juvenile Chinook salmon outmigration on the lower Sacramento River near Knights Landing also shows a relationship between timing and magnitude of flow in the Sacramento River and the

⁷¹ DFG Report at p. 44.

migration timing and survival of Chinook salmon approaching the Delta from the upper Sacramento River basin (Snider and Titus 1998, 2000a, 2000b, 2000c, and subsequent draft reports and data as cited in DFG 2010a). Outmigration timing of juvenile late-fall, winter, and spring-run Chinook salmon from the upper Sacramento River basin depends on increases in river flow through the lower Sacramento River in fall, with significant precipitation in the basin by November to sustain downstream migration of juvenile Chinook salmon approaching the Delta (Titus 2004). Sacramento River flows at Wilkins Slough of 15,000 to 20,000 cfs following major precipitation events are associated with increased outmigration (DFG 2010a, NMFS 7 as cited in SWRCB 2010). Delays in precipitation producing flows result in delayed outmigration which may result in increased susceptibility to in-river mortality from predation and poor water quality conditions (DFG 2010a). Allen and Titus (2004) suggest that the longer the delay in migration, the lower the survival of juvenile salmon to the Delta. To encourage and support outmigration, Juvenile Chinook salmon appear to need increases in Sacramento River flow that correspond to flows in excess of 20,000 cfs at Wilkins Slough by November with similar peaks continuing past the first of the year (DFG 2010a). Pulse flows in excess of 15,000 to 20,000 cfs may also be necessary to erode sediment in the upper Sacramento River downstream of Shasta to create turbid inflow pulses to the Delta that hide young salmon from predators (AR/NHI 1 as cited in SWRCB 2010).⁷²

This analysis and rationale for fall Sacramento River flows in excess of 15,000 cfs is flawed in two significant ways. First, the data and reports cited here are based upon DFG's operation of rotary screw traps (RST) at Knights Landing. The ability of RSTs to capture outmigrating juvenile salmonids is itself highly sensitive to factors like river flow, turbidity, and fish size (see Montgomery *et al.* 2007).⁷³ It is inappropriate to report and analyze raw RST catch data as indicative of survival or abundance without specifically accounting for the efficiency of the RST. Unfortunately, DFG does not conduct such trap efficiency experiments for Knights Landing RSTs, nor do they generate estimates of juvenile salmonid passage which account for factors like river flow, turbidity and fish size. Thus, raw catch at Knights Landing cannot appropriately be used to draw the conclusions indicated in the draft report.

Second, analyzing catch from Sacramento River trawls (at Sherwood Harbor) conducted by the U.S. Fish and Wildlife Service provides another information source. Trawl data is particularly valuable because it is thought to be less subject than RSTs to very low and variable capture efficiency. Figure 12 depicts Sacramento Trawl catch from 1995-2001 (based upon publicly available data from the BDAT website). This data shows, for example, that Jan-Apr winter-run Chinook emigrants are consistently detected in the Sacramento Trawl. Low catch in the Knights Landing RST during this period was presented in the DFG Report as evidence of poor survival or delayed emigration of juvenile salmonids due to low flow conditions. The more reliable catch data from the Sacramento River trawl illustrates that poor and unknown trap efficiency is a more reasonable explanation for observed patterns of juvenile salmonid catch at the Knights Landing RSTs. It is not clear why the report or background materials by resource agencies did not properly evaluate available data on Sacramento River juvenile salmonid emigrants. However, it is clear that the analysis and rationale based upon Knights Landing RST catch to support high fall Sacramento River flows is significantly flawed and is scientifically insufficient to support higher Sacramento River flows in the fall.

⁷² DFG Report at p. 45.

⁷³ Montgomery J, Gray A, Watry C, Pyper B. 2007. Using rotary screw traps to determine juvenile Chinook salmon outmigration abundance, size and timing in the lower Merced River, California. Available at: http://www.fishsciences.net/reports/2007/fws15-22_mercedmon_report-fin_2007-1030.pdf

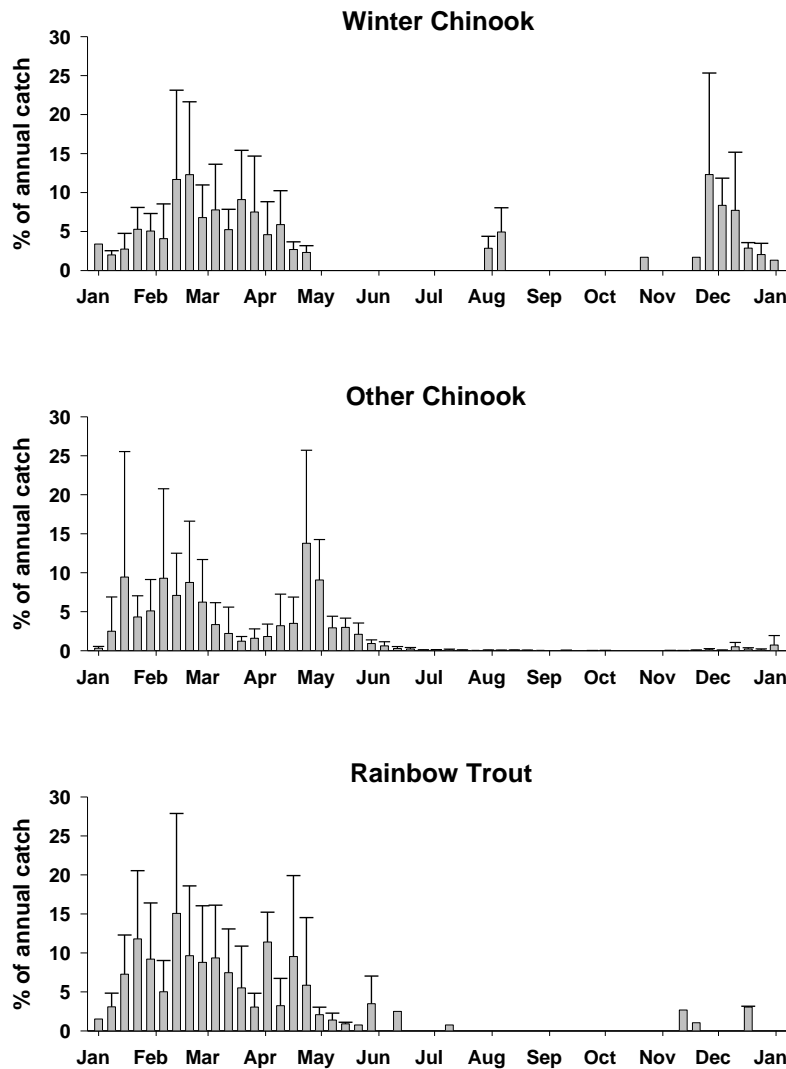


Figure 12. Average percentage of the annual catch taken each week for the specified race of juvenile salmonids in the trawl fished at Sacramento by USFWS, 1995-2001. Whisker lines are standard deviations.

c. DFG used incorrect temperature criteria cited for juvenile salmonids

In describing life history characteristics for salmonids, the DFG Report states, “Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54°F to 57°F (Brett 1952).”⁷⁴ This statement is incorrect for two reasons. First, contrary to the clear implication, Brett (1952)⁷⁵ provides no specific assessment of optimal temperatures of juvenile Chinook in the Sacramento-San Joaquin Delta. Second, more recent studies, including those specifically addressing Central Valley salmonids, show that Chinook juveniles can achieve optimal growth at temperatures as warm as 65°F (see synthesis provided by Marine 1997; Zedonis and Newcomb 1997; Clark and Shelbourn 1985),⁷⁶ while steelhead can achieve optimal growth at temperatures as warm as 68°F (Cech and Myrick 1999; EPA

⁷⁴ DFG Report at p. 40.

⁷⁵ *Ibid.*

⁷⁶ Marine, Keith Richard. 1997. Effects of Elevated Water Temperature on Some Aspects of the Physiological and Ecological Performance of Juvenile Chinook Salmon, Implications for Management of California Central Valley, UCD, Masters Thesis; Zedonis, Paul A and Newcomb, Tammy J. 1997. An Evaluation of Flow and Water Temperatures During the Spring for Protection of Salmon and Steelhead Smolts in the Trinity River, California, United States Fish and Wildlife Service; Clarke, Craig W and Shelbourn, John E. 1985. Growth and Development of Seawater Adaptability by Juvenile Fall Chinook Salmon (*Oncorhynchus tshawytscha*) in relation to Temperature. *Aquaculture*. 45: 21-31.

2001).⁷⁷ The available data do not support the temperature criteria cited in the draft report.

d. DFG misuses Vogel (2004)

The DFG Report supports its view that project exports adversely affect salmonid survival by reference to a 2004 radio telemetry study conducted by David A. Vogel. Referring to this study, the DFG Report states (p. 55):

Analyses indicate that tagged fish may be more likely to choose to migrate south toward the export facilities during periods of elevated diversions than when exports were reduced.

This interpretation conflicts directly with Vogel (2004),⁷⁸ which concluded:

“These experiments could not explain why some fish moved off the mainstem San Joaquin River into south Delta channels. Due to the wide variation in hydrologic conditions during the two central Delta studies, it was difficult to determine the principal factors affecting fish migration. Based on limited data from these studies, it may be that a combination of a neap tide, reduced exports, and increased San Joaquin River flows is beneficial for outmigrating smolts, but more research is necessary. (emphasis added.)

This is a non-trivial error as no other studies support the hypothesized effect of increased exports, where migratory juvenile salmonids are drawn away from the mainstem San Joaquin River. The use of Vogel (2004) in the biological opinion the National Marine Fisheries Service prepared on the continued operations of the CVP and SWP was described as not rational nor scientifically justified by a federal judge⁷⁹ and should not be used to support specific flow recommendations in the DFG Report.

e. DFG unduly relied on particle tracking model (PTM) results to assess effect of exports on migratory juvenile salmonids.

The DFG Report relies directly on PTM results and interpretations from the NMFS BiOp regarding the effect of exports on juvenile salmonids.⁸⁰ The best available science shows the dispute over the use of PTM to model juvenile salmon movement is not a dispute among scientists, but instead is a dispute between NMFS’ unsupported findings and virtually all of the scientific evidence currently available to DFG. Simply put, PTM is not a valid surrogate for movement of juvenile salmonids which are volitional and can swim at rates at least twice the level of currents in the Delta.

1. DFG fails to address the published scientific literature stating that the PTM does not explain salmon behavior

The DFG Report should have considered the published literature establishing that migrating salmon do not travel as neutrally-buoyant particles. Baker and Morhardt (2001) compared the transit time and migration patterns of released coded wire tagged salmon and simulated neutrally-buoyant particles. Baker and Morhardt conclude that salmon smolt passage through the Delta “is considerably shorter than the transit time for neutrally-buoyant tracer particles, at least in hydraulic simulations.”⁸¹ According to the authors, “Figure 5 (reproduced below as Figure 13) shows an example comparing the speed of smolt

⁷⁷ Cech JJ, Myrick CA. 1999. Steelhead and Chinook salmon bioenergetics: temperature, ration, and genetic effects. Technical completion report – Project No. UCAL-WRC-W-855. University of California Water Resource Center; U.S. Environmental Protection Agency. 2001. Temperature interaction – issue paper 4. Report No. EPA-910-D-01-004. EPA.

⁷⁸ Vogel, David A. 2004. Juvenile Chinook salmon radio-telemetry studies in the northern and central Sacramento-San Joaquin Delta 2002-2003. Report to the National Fish and Wildlife Foundation.

⁷⁹ OCAP BiOp Preliminary Injunction Findings of Fact and Conclusions of Law, Doc 346 at 122-123.

⁸⁰ DFG Report at p. 55.

⁸¹ Baker PF, Morhardt JE. 2001. Survival of Chinook salmon smolts in the Sacramento- San Joaquin Delta and Pacific Ocean. Pages 163-182 in R.L. Brown, Editor. Contributions to the Biology of Central Valley Salmonids, Volume 2, Fish Bulletin 179. California Department of Fish and Game, Sacramento, California, p. 173.

passage and the speed of tracer particles for a release made on April 4, 1987, in which 80% of the smolts were estimated to have been recovered after two weeks, but only 0.55% of the tracer particles were recovered after two months.”⁸² Comparing smolt migration and particle distribution patterns, Baker and Morhardt (2001) remarked: “Not only do the tracer particles which reach Chipps Island take a long time to get there, but most of them go somewhere else.”⁸³ Baker and Morhardt (2001) reported: “That somewhere else is the CVP and SWP pumps, at least for the hydraulic simulations available to us. Figure 13 shows that for the April 27, 1987 simulations, 77% of the tracer particles ended up at the export pumps, while only 13% of the smolts arrived there.”⁸⁴ The authors characterize these differences as “striking” and explain that the results are due to the fact that “smolts actively swim toward the ocean, and the bigger they are the faster they do it.”⁸⁵

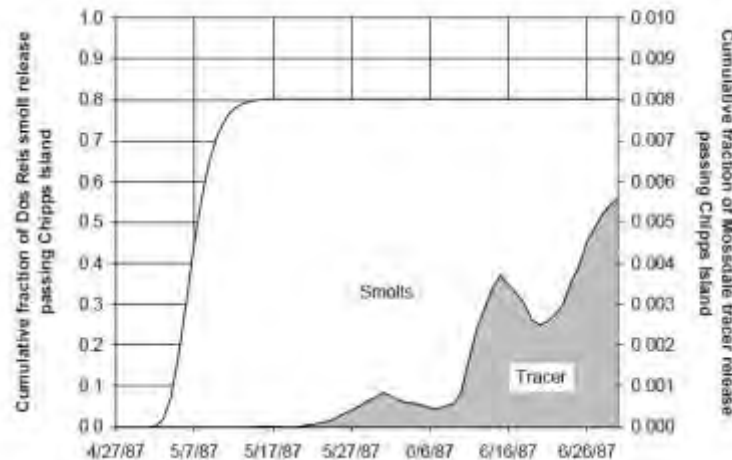


Figure 13 from Baker and Morhardt (2001). Comparisons of the movements of salmon smolts and passive particles released near the head of Old River on April 27, 1987. Cumulative recoveries at Chipps Island of smolts released at Dos Reis, and simulated mass flux past Chipps Island of tracer material released at Mossdale. The smolt recovery data have been fitted to an inverse Gaussian distribution. Hydraulic simulations by Flow Science (1998).

The United States Bureau of Reclamation (“Reclamation”) and the Department of Water Resources (“DWR”) have also conducted analyses comparing observed coded wire tag recoveries with predicted recovery timing and location as predicted by PTM and concluded:

The result of the comparison of timing and magnitude of CWT Chinook recoveries and PTM particles passing Chipps Island shows that there is no correlation. There are factors other than hydrodynamics affecting juvenile Chinook emigration through the south Delta not accounted for in the PTM. Based on the 24 experiments graphed in this evaluation, the PTM results are an adequate surrogate for “timing” of salmonid emigration in only very high flow years like 1995, 1998 and 2006. But for the rest of the years, intermediate and low flow years, the PTM results would result in significant project regulation 3 to 6 weeks beyond emigration timing.⁸⁶

DFG’s reliance on the PTM to predict salmon migration is therefore misplaced.

⁸² *Ibid.*

⁸³ *Ibid.*

⁸⁴ *Ibid.*

⁸⁵ *Id.* at p. 175.

⁸⁶ Comments by Ronald Milligan, United States Bureau of Reclamation (in coordination with Department of Water Resources), to Maria Rea, National Marine Fisheries Service, Regarding Additional comments on the NMFS draft biological opinion, April 24th 2009, page 4.

2. NMFS and DFG failed to address the PTM limitations described by Kimmerer and Nobriga (2008)

DFG relied on the NMFS BiOp but the analysis of the PTM is flawed. In support of their RPA, NMFS expressly relies upon the PTM results as described by Kimmerer and Nobriga (2008). The NMFS BiOp states: “NMFS considers this information useful in analyzing the potential „zone of effects” for entraining emigrating juvenile and smolting salmonids.”⁸⁷ A key failure of the NMFS BiOp is its failure to recognize and address the model’s limitations as described by Kimmerer and Nobriga (2008).

Kimmerer and Nobriga (2008) note that the PTM model “has not been calibrated.”⁸⁸ Calibration allows for the testing of model outcomes against the full array of evidence in the real world. Kimmerer and Nobriga further warn that “comparisons with field data described above do not constitute a sufficient calibration.”⁸⁹ However, contrary to Kimmerer and Nobriga’s warnings, NMFS’ PTM technical memorandum asserts that “[t]he model has been calibrated with data from monitoring stations throughout the Delta,” Stuart (2009).⁹⁰ NMFS does not explain how it has transformed a non-calibrated PTM model into a calibrated PTM model that is consistent with Kimmerer and Nobriga (2008).

NMFS’ use of PTM does not apply a simulation period that corresponds to anticipated fish behavior. Given the rapid and directed movements of salmonid smolts, it is inappropriate to use the fate of particles integrated over weeks or months to even roughly assess salmonid smolt survival; they simply do not act like weightless, behaviorless particles (Baker and Morhardt 2001).⁹¹ Kimmerer and Nobriga agree stating, “Salmon smolts are not particles; they have complex behaviors and are strong swimmers. We do not know what cues them to navigate downstream and out to the ocean.”⁹² They also recognized that the time horizon used in the model is, “...too long to be useful for analyzing the movements of larval fish. By the end of the modeled time period, the fish have already metamorphosed, and their behavior would have become more complex.” Though several figures in the NMFS PTM memorandum depict the fate of particles at five day increments, the only instance where the memorandum specifically mentions PTM results over a short time horizon is where NMFS reports that “the typical pattern following injection at station 912 was a period of several days with little or no entrainment.”⁹³ Thus, in the one instance where a time horizon of only several days was discussed, which is more typical of emigrating smolts, the results indicated no material entrainment effect.

NMFS’ underlying premise for using PTM conflicts with the recommendations of Kimmerer and Nobriga (2008). As noted above, NMFS invoked the PTM and the Kimmerer and Nobriga (2008) study because it “considers this information useful in analyzing the potential „zone of effects” for entraining emigrating juvenile and smolting salmonids.” (NMFS BiOp at p. 361.)⁹⁴ However, Kimmerer and Nobriga expressly stated that “[w]e are, furthermore, not inclined to define a „zone of influence” of the pumps on the basis of our results.”⁹⁵ Thus, NMFS chose to use the PTM precisely for the role that Kimmerer and Nobriga

⁸⁷ NMFS BiOp at p. 361.

⁸⁸ Kimmerer WJ, Nobriga MJ. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin delta using a particle tracking model. San Francisco Estuary and Watershed Science 6(1), Art. 4, p. 17.

⁸⁹ *Id.* at p. 5.

⁹⁰ Stuart J. 2009 Particle Tracking Model results for Old and Middle River flow manipulation. Technical memorandum dated June 3, 2009, p 1.

⁹¹ Baker PF, Morhardt JE. 2001. Survival of Chinook salmon smolts in the Sacramento- San Joaquin Delta and Pacific Ocean. Pages 163-182 in R.L. Brown, Editor. Contributions to the Biology of Central Valley Salmonids, Volume 2, Fish Bulletin 179. California Department of Fish and Game, Sacramento, California.

⁹² Kimmerer WJ, Nobriga MJ. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin delta using a particle tracking model. San Francisco Estuary and Watershed Science 6(1), Art. 4, p. 18.

⁹³ Stuart J. 2009 Particle Tracking Model results for Old and Middle River flow manipulation. Technical memorandum dated June 3, 2009, p 3.

⁹⁴ NMFS BiOp at p. 361.

⁹⁵ Kimmerer WJ, Nobriga MJ. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin delta using a particle tracking model. San Francisco Estuary and Watershed Science 6(1), Art. 4, p. 18.

declined to recommend it for. The DFG Report makes a similar mistake.

f. DFG's reliance on the NMFS BiOp recommended OMR and San Joaquin River inflow/exports ratio as restrictions are not supported by the best available science.

The DFG Report relies specifically on OMR and San Joaquin River inflow to export restrictions required by the NMFS BiOp.⁹⁶ As the summary below indicates, these recommendations are not supported, and in many cases, are directly contradicted by, the best available science.

1. Best available science does not support export restrictions contained in the NMFS BiOp San Joaquin River inflow/export ratio.

The NMFS BiOp contains two components related to exports and San Joaquin River flows: (1) a San Joaquin River flow requirement measured at Vernalis; and (2) a limit on export pumping operations in the southern Delta.⁹⁷ These same requirements have apparently been adopted as Delta flow recommendations in the DFG Report.⁹⁸

Depending upon flow conditions in the San Joaquin River, the NMFS BiOp limits collective CVP and SWP pumping from April 1 to May 31 to a 4-to-1 Vernalis inflow/export ratio. NMFS contends that this export limit will benefit outmigrating San Joaquin River basin and Calaveras River steelhead and that reduced project pumping will assist the survival of Sacramento River salmonids.⁹⁹ However, the evidence collected during 10 years of experimental flows in the VAMP program and tagging and telemetry studies of salmon outmigration indicates that rate of pumping is not a significant factor in determining salmonid survival. Neither NMFS, the SWRCB, nor the DFG Report have provided any evidence to support the 4:1 Vernalis inflow/export ratio as being an appropriate export limit for the protection of salmonids. In fact, the Federal District Court for the Eastern District of California has already determined that NMFS cannot justify its selection of the 4:1 ratio in its BiOp, as opposed to any other ratio and that this was a “quintessential example of arbitrary action.”¹⁰⁰

In Appendix 5 of the BiOp, NMFS purports to find biological support for its adoption of the 4:1 Vernalis inflow/export ratio from Figures 10 and 11 in its appendix.¹⁰¹ However, Figure 10 is a regression analysis that only considers the relationship between Vernalis flow and salmon smolt survival. Project exports are not a factor considered in the analysis. Figure 11 reviews the relationship between the Vernalis inflow/export ratio and returning adult escapement 2.5 years later, but nothing in the Figure 11 analysis or Appendix 5's summary of the analysis explains how NMFS derived the 4:1 ratio from the data displayed in Figure 11. The DFG's own 2005 review of project exports and adult escapement 2.5 years later in the Tuolumne River disclosed that “no correlation” can be found between these variables.¹⁰² Mesick *et al.* (2007) confirms DFG's 2005 assessment.¹⁰³

The DFG Report's reliance on the 4:1 inflow to export ratio required under the biological opinion the National Marine Fisheries Service prepared for the continued operation of the CVP and SWP is further undermined by a separate technical memorandum dated June 3, 2009, supplied with the biological opinion. There, NMFS attempts to justify the 4:1 ratio based upon a 1989 study by Kjelson and

⁹⁶ DFG Report at pp. 55-56.

⁹⁷ NMFS BiOp at 641-645.

⁹⁸ DFG Report at Appendix A, Table 4.

⁹⁹ NMFS BiOp at p. 645.

¹⁰⁰ The Consolidated Salmon Cases, Case 1:09-cv-01053-OWW-DLB, Doc No. 347, p. 116.

¹⁰¹ NMFS BiOp at Appendix 5, pp. 20-21.

¹⁰² Marston D. 2005. San Joaquin River fall-run Chinook salmon population model, final draft 11/28/2005. California Department of Fish and Game, San Joaquin Valley Southern Sierra Region, p.15, Fig. 24.

¹⁰³ Mesick, C., et al. 2007. Limiting Factor Analyses and Recommended Studies for Fall-Run Chinook salmon and Rainbow Trout in the Tuolumne River, p. 11.

Brandes,¹⁰⁴ however, their study did not find any correlation between CVP and SWP pumping and salmon survival. Instead, the study confirmed what other studies have shown, that a positive correlation exists between salmon survival and San Joaquin river flow at Vernalis, again without identification of causal factors. The technical memorandum also cites to the SJRGA 2007 Annual Technical Report in support of the 4:1 ratio.¹⁰⁵ However, the 2007 report declines to reach this conclusion and instead states: “The relationship of survival to exports is difficult to detect based on the data gathered to date.”¹⁰⁶ The report continues by stating that “[t]he escapement data for adult salmon indicate that the flow/export ratio explains more of the variability in the adult escapement than flow alone without the HORB, but the smolt survival data is too limited to detect these effects, if they are real.”¹⁰⁷ Thus the 2007 report does not support the 4:1 ratio, but instead voices clear doubts as to whether the relationship between exports and salmonid survival is in fact “real.” In short, neither Kjelson and Brandes 1989 nor the 2007 Annual Technical Report supports NMFS’s decision to adopt a 4:1 inflow/export ratio.

Notwithstanding more than twenty years of scientific research and investigation directly focused on this precise subject, San Joaquin River fishery studies have not produced any evidence showing a negative relationship between salmonid survival and project pumping. A review of the multiple studies shows the relationship between salmonid survival and CVP and SWP pumping have either failed to establish any statistical relationship between exports and survival, or have surprisingly shown a positive relationship between pumping rates and survival. The excerpts below provide specific examples.

- Kjelson, Loudermilk, Hood, and Brandes: “**Survival of tagged smolts released under low export conditions was not greater than for those released under high export conditions** (Table 4). This was an unexpected result as we believed conditions for survival should have improved when exports were lowered, since direct losses at the Project facilities were decreased, flow in the mainstem San Joaquin was increased and reverse flows in the Delta were eliminated.” (Emphasis added)¹⁰⁸
- Brandes and McLain: “To determine if exports influenced the survival of smolts in the San Joaquin Delta, experiments were conducted in 1989, 1990 and 1991 at medium/high and low export levels. Results were mixed showing in 1989 and 1990 **that survival estimates** between Dos Reis and Jersey Point **were higher with higher exports** whereas in 1991 between Stockton and the mouth of the Mokelumne River (Tables 11 and 12) survival was shown to be lower (0.008 compared to 0.15) when exports were higher. . . . In addition, results in 1989 and 1990 also showed **that survival indices** of the upper Old River groups relative to the Jersey Point groups **were also higher during the higher export period**, but overall still about half that of the survival of smolts released at Dos Reis (Table 11).” (Emphasis added)¹⁰⁹
- San Joaquin River Group Authority: “Regression of exports to smolt survival without the HORB were weakly or not statistically significant (Figure 5-17) using both the Chipps Island and Antioch and ocean recoveries, **but both relationships indicated survival increased as exports increased.**” (Emphasis added)¹¹⁰

¹⁰⁴ NMFS BiOp at Appendix 5, pp. 5-10 and 74, *citing*, Kjelson M, Brandes P. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin Rivers, California. *Canadian Special Publication of Fisheries and Aquatic Sciences* 105.

¹⁰⁵ SJRGA 2007 Annual Technical Report in support of the 4-to-1 ratio, pp. 20-21 and 74.

¹⁰⁶ San Joaquin River Group. 2007 annual technical report, San Joaquin River Agreement, Vernalis Adaptive Management Plan. January 2008. p. 6.

¹⁰⁷ *Ibid.*

¹⁰⁸ Kjelson, Martin, Loudermilk, Bill, Hood, Dennis, and Brandes, Pat. 1990. The Influence of San Joaquin River Inflow, Central Valley and State Water Project Exports and Migration Route on Fall-Run Chinook Smolt Survival in the Southern Delta During the Spring of 1989,” Report to Stockton, CA, FWS Fishery Assistance Office, p. 12.

¹⁰⁹ Brandes, Patricia and McLain, Jeffery S. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the San Sacramento-San Joaquin Estuary,” Fish Bulletin 179, Vol. 2, p. 89.

¹¹⁰ San Joaquin River Group. 2005 Annual technical report, San Joaquin River Agreement, Vernalis Adaptive Management Plan. January 2006, p. 66.

- California Department of Fish and Game: “There is **no correlation between exports and adult salmon escapement** in the Tuolumne River two and one-half years later (Figure 24).” (Emphasis added)¹¹¹
- Mesick, McLain, Marston and Heyne: “[P]reliminary correlation analyses suggest that the combined State and Federal export rates during the smolt outmigration period (April 1 to June 15) **have relatively little effect** on the production of adult recruits in the Tuolumne River compared to the effect of winter and spring flows. Furthermore, **reducing export rates** from an average of 264% of Vernalis flows between 1980 and 1995 to an average of 43% of Vernalis flows and installing the head of Old River Barrier between 1996 and 2002 during the mid-April to mid-May VAMP period **did not result in an increase in Tuolumne River adult recruitment** (Figures 3 and 17).” (Emphasis added)¹¹²
- Ken B. Newman: “The Bayesian hierarchical model analyzed the multiple release and recovery data, including Antioch, Chipps Island, and ocean recoveries, simultaneously.... There was **little evidence for any association between exports and survival**, and what evidence there was pointed towards a somewhat **surprising positive association with exports**.” (Emphasis added)¹¹³
- Lastly, in a published 2001 paper, Baker and Morhardt summarized the results of their export/salmon survival research by observing: “There is **no empirical correlation at all between survival in Lower San Joaquin River and the rate of CVP-SWP export**.” Based upon their review of the evidence, Baker and Morhardt concluded that “**no relationship between export rate and smolt mortality** suitable for setting day-to-day operating levels has been found.” (Emphasis added)¹¹⁴

It might be argued that these examples are cherry picked; however, this is not the case. There are no statistical analyses that show a negative relationship between San Joaquin River salmonid survival and CVP and SWP pumping levels. As the SJRGA 2005 Annual Technical Report concluded, “[e]xports do not appear to explain additional variability in smolt survival over that using flow alone, in data obtained with the HORB in 1994, 1997 and between 2000 and 2004.”¹¹⁵

The DFG Report nonetheless implicates CVP and SWP pumping as a causal factor in salmonid survival by conflating San Joaquin River flow and pumping levels into an inflow/export ratio. This conflation of flow and export data does not provide scientific support for inflow/export restrictions.

In fact, DFG has previously independently confirmed that San Joaquin River salmonid production does not correlate to CVP and SWP pumping. In a 2005 study entitled “San Joaquin River Fall-run Chinook Salmon Population Model”, DFG observed:

In every instance where salmon production was high, Vernalis flows are in excess of 10,000 cfs. Conversely when salmon production was low, Vernalis flow levels are less than 2,000 cfs (Figure 19). The question becomes is it the flow, or the exports?” In an attempt to answer this question, DFG took a close look at smolt survival data on the San Joaquin River. The DFG study found that “Smolt survival data collected during VAMP shows **that juvenile survival increases as exports increase** (Figure 19). In addition, smolt survival as a function of the exports to Vernalis flow

¹¹¹ California Department of Fish and Game. “Final Draft 11-28-05 San Joaquin River Fall-run Chinook Salmon Population Model,” p. 15.

¹¹² Mesick, McLain, Marston and Heyne. “Draft Limiting Factor Analyses & Recommended Studies for Fall-run Chinook Salmon and Rainbow Trout in the Tuolumne River” (February 27, 2007), p. 25.

¹¹³ Newman, Ken B. 2008. “An Evaluation of Four Sacramento-San Joaquin River Delta Juvenile Salmon Survival Studies,” p. 76.

¹¹⁴ Baker, Peter and Marhardt, Emil. 2001. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179, Vol. 2, p. 181.

¹¹⁵ San Joaquin River Group. 2005 annual technical report, San Joaquin River Agreement, Vernalis Adaptive Management Plan. (January 2006) p. 63.

ratio has a low correlation (Figure 20), indicating that **Delta export level, relative to Delta inflow level, does not influence juvenile salmon survival** on a regular, normal, or repetitive pattern. (Emphasis added)¹¹⁶

DFG further observed: “Here again, the variable that seems to be controlling salmon production (*e.g.* survival) is spring Delta inflow, not spring Delta export.”¹¹⁷ DFG’s San Joaquin River Fall-run Chinook Salmon Population Model Report then reviewed all available salmon smolt survival data and adult salmon escapement data available and stated:

In conclusion, while the influence of Delta exports upon SJR salmon production is not totally clear, overall it appears that **Delta exports are not having the negative influence upon SJR salmon production** they were once thought to have. Rather it appears that Delta inflow (*e.g.*, Vernalis flow level) is the variable influencing SJR salmon production, and that increasing flow level into the Delta during the spring months results in substantially increased salmon production. (Emphasis added)¹¹⁸

DFG was sufficiently convinced of the “lack of substantial cause and effect relationships” between Delta exports and salmon survival that in developing CDFG’s San Joaquin River salmon model, CDFG expressly excluded consideration of Delta exports as a factor in the model’s development.¹¹⁹

In light of the above, the DFG Report’s adoption of the NMFS BiOp’s San Joaquin River 4:1 inflow/export ratio is not supported by the best available science.

2. Best available science does not support calendar based restrictions on Old and Middle River flows

The DFG Report proposes restrictions on Old and Middle River flows, which are not support by science. The DFG Report relies heavily upon the biological opinion that NMFS prepared for the continued operation of the CVP and SWP for those restrictions. However, the biological opinion itself is flawed. According to NMFS, calendar based OMR restrictions are intended to “[r]educe the vulnerability of emigrating juvenile winter-run, yearling spring-run, and CV [Central Valley] steelhead within the lower Sacramento and San Joaquin rivers to entrainment into the channels of the South Delta and at the pumps due to the diversion of water by the export facilities in the South Delta.”¹²⁰ The RPA purportedly achieves this objective by requiring the export projects to limit exports to a level that produces flows in Old and Middle River (OMR) no more negative than -5,000 cubic feet per second (cfs) to -2,500 cfs.¹²¹ The action triggers for the OMR flow limits are either:

- A calendar based trigger that mandates the CVP and the SWP to achieve OMR flows of -5,000 cfs, starting on January 1st and ending on June 15th of every year. This trigger forces the CVP and SWP to reduce pumping to meet the OMR flow requirement even if the pumping operations fail to entrain a single salmon smolt during this six month period.¹²²
- A salvage based trigger that requires the projects to achieve OMR flows as low as -2,500 cfs depending upon the amount of salmonid salvage that has occurred at the export facilities.¹²³

¹¹⁶ Marston D. 2005. San Joaquin River Fall-run Chinook Salmon Population Model Final Draft. Report to California Department of Fish and Game, p. 14.

¹¹⁷ Marston D. 2005. San Joaquin River Fall-run Chinook Salmon Population Model Final Draft. Report to California Department of Fish and Game, p. 14.

¹¹⁸ *Id.* at p. 15

¹¹⁹ *Id.* at p. 17

¹²⁰ NMFS BiOp at p. 648

¹²¹ NMFS BiOp at 648-650.

¹²² NMFS BiOp at p. 648.

¹²³ *Ibid.*

In its May 18, 2010, Findings of Fact and Conclusions of Law re: Plaintiffs' Request for Preliminary Injunction, the federal court concluded: "NMFS's choice of -5,000 cfs as the calendar based ceiling is not scientifically justified and is not based on best available science."¹²⁴

The calendar based component of OMR restrictions should not be supported in the DFG Report for the following, previously presented, reasons: (1) evidence does not support NMFS' use of PTM as a tool to explain salmonid behavior; (2) evidence does not support NMFS' contention that project export operations alter salmon behavior and therefore adversely affect their survival; and (3) a federal court has already found that this restriction is not based on the best available science.¹²⁵

In addition to the PTM results, the NMFS BiOp, and therefore the DFG Report, relies upon a series of fishery studies to support the OMR limits. However, review of these studies shows that, at best, they provide inconclusive or ambiguous support for the action.

Misattribution of Newman (2008). NMFS BiOp, Appendix 5 cited to a 2008 paper prepared by Dr. Ken B. Newman for the proposition that the Delta Action 8 studies of Sacramento River coded wire tag releases, "...found a statistically significant negative association between survival of fish moving through the Delta interior and export volume."¹²⁶ Based upon its review of this study, the NMFS BiOp states that "[t]here was a negative association between export volumes and the relative survival of released salmonids."¹²⁷ However, Dr. Newman did not use the word "significant" in describing the relationship because he concluded from his Bayesian analysis that there was very little difference in the model results with exports and without exports. Newman (2008) actually states, "The preferred model based on DIC [a measure of model fit] is the multinomial with log transformed θ and uniform priors for the [variances] (Table 11), but all the multinomial models yielded quite similar results."¹²⁸ The DIC for this model, 427.0, however, was only slightly less than the DIC for the models without exports (the "Interior" models where minimum DIC was 427.7)."¹²⁹

Thus, Dr. Newman concluded that the DIC value for a model without exports was not much higher than the corresponding model with exports. In a follow-up analysis of the Delta Action 8 data, Newman and Brandes found that the "relationship between exports and the relative survival of Georgiana Slough releases seems relatively weak" and they could not conclude that "exports are the cause of this lower relative survival," Newman and Brandes (2008).¹³⁰

Improper extrapolation from Perry and Skalski (2008). The NMFS BiOp (and therefore DFG) has similarly misapplied the 2008 study by Perry and Skalski. Specifically referring to the results of Perry and Skalski (2008), the NMFS BiOp explains that "[t]he probability of ending up at the Delta export facilities or remaining in the interior delta waterways increases with increased export pumping, particularly for those fish in the San Joaquin River system."¹³¹ However, the Results and Discussion sections of Perry and Skalski (2008) do not contain any reference to project exports. Moreover, Perry and Skalski (2008) expressly recognizes that "[c]urrently, there is limited understanding of how water management actions in the Delta affect population

¹²⁴ Case 1:09-cv-01053-OWW-DLB Document 347 at p. 6

¹²⁵ Case 1:09-cv-01053-OWW-DLB Document 347 at p. 65

¹²⁶ NMFS BiOp, Appendix 5 at p. 9

¹²⁷ NMFS BiOp at p. 373

¹²⁸ Newman, Ken B. 2008. "An Evaluation of Four Sacramento-San Joaquin River Delta Juvenile Salmon Survival Studies," p. 76.p. 59.

¹²⁹ *Ibid.*

¹³⁰ Newman, Ken B, and Brandes, patricia. 2010. Hierarchial Modeling of Juvenile Chinook Salmon Survival as a Function of Sacramento- San Joaquin Delta, *North American Journal of Fisheries Management*, 30: 157-169, p. 59.

¹³¹ NMFS BiOp at p. 383.

distribution and route-specific survival of juvenile salmon.”¹³²

Misstatement of Vogel (2004) conclusions. As described previously, the NMFS BiOp and the DFG Report both misrepresent the findings of Vogel (2004)¹³³ in an attempt to support OMR flow restrictions. As previously discussed, a federal court determined that NMFS’ use of Vogel (2004) to support its BiOp was not rational and not scientifically justified.

In light of all the examples provided, it is clear that the DFG Report’s acceptance of the OMR flow restrictions required by the National Marine Fisheries Service is not supported by the best available science.

VIII. DFG failed to recognize that while there is a relationship between outflow (X2) and starry flounder abundance, no causal mechanism has been identified and species abundance has recovered.

Delta outflow criteria for starry flounder are based on the X2-abundance relationship asserted for Delta and longfin smelt and bay shrimp, even though high outflows are noted as only indirectly correlating with bay shrimp abundance. Kimmerer (2002a, 2002b)¹³⁴ and Kimmerer *et al.* (2009)¹³⁵ are offered as the only support for an outflow-abundance relationship for starry flounder, none of which offers a causal mechanism. In the case of starry flounder, the State Water Board’s Flow Criteria Report recognizes that DFG was the only participant to submit outflow recommendations and indicates that the proposed criteria are “consistent with California Department of Fish and Game recommendation for starry flounder.”¹³⁶ DFG’s testimony and exhibits do state that starry flounder are associated with March-June outflows, offering several hypotheses for causal mechanisms, none of which are established by the best available science: (1) outflows can provide chemical cues to larvae and juveniles to facilitate locating estuarine nursery habitat; (2) high outflows generate bottom-oriented upstream-directed gravitational currents that assist immigration; and (3) flows enhance the area of low salinity habitat selected by young starry flounder.

Kimmerer (2002b) has shown lower relative abundance per unit X2 after the invasion of *C. amurensis*, evidence of food limitation.¹³⁷ Because of the profusion of *C. amurensis*, it cannot be stated that higher outflows will translate into more food. DFG admits in its written summary that flows alone are insufficient to sustain or recover the low salinity zone ecosystem.¹³⁸ Without considering what other actions need to be taken as part of a suite of actions to maintain abundances of starry flounder, outflow recommendations are not supportable.

The DFG Report omits an important point about starry flounder that is contained in the SWRCB flow criteria report, which states: “Population abundance of young of the year and one year old starry flounder have been measured by the San Francisco Otter Trawl Study since 1980 and reported as an annual index (Kimmerer *et al.* 2009).¹³⁹ The index declined between 2000 and 2002 but has since recovered to values

¹³² Perry, Russell W, and Skalski, John R. 2008. Migration and Survival of Juvenile Chinook Salmon Through the Sacramento-San Joaquin River Delta during the Winter of 2006-2007, p. 3.

¹³³ Vogel, David A. 2004. Juvenile Chinook salmon radio-telemetry studies in the northern and central Sacramento-San Joaquin Delta 2002-2003. Report to the National Fish and Wildlife Foundation.

¹³⁴ Kimmerer WJ. 2002a. Effects of freshwater flow on abundance of estuarine organisms; Physical effects or trophic linkages? *Marine Ecology Progress Series* 243:39-55; Kimmerer WJ. 2002b. Physical, biological, and management responses to variable freshwater flow in the San Francisco estuary. *Estuaries* 25(6B): 1275-1290.

¹³⁵ Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuaries and Coasts* 32:375-389.

¹³⁶ State Water Board Flow Criteria at p. 83.

¹³⁷ Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuaries and Coasts* 32:375-389.

¹³⁸ DFG at p. 2

¹³⁹ Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuaries and Coasts* 32:375-389.

in the 300 to 500 range. The median index value for the 29 years of record is 293.”¹⁴⁰ Hence, the available data suggests that existing flow criteria since 2002 (D-1641 as amended) are sufficient to maintain starry flounder abundances.

IX. The net effect of Delta outflow indicates no actual increase in American shad abundance.

The DFG Report asserts that American shad year class strength correlates positively with freshwater outflow during spawning and nursery periods.¹⁴¹ To support the assertion of an X2-abundance relationship for American shad, the draft report cites Kimmerer (2002a) and Kimmerer *et al.* (2009).¹⁴² Stevens and Miller (1983) is also indirectly cited to argue for an increase in habitat as a possible causal mechanism for the X2-abundance relationship.¹⁴³ Yet it is acknowledged that no causal relationship for an X2-abundance relationship is known.¹⁴⁴ In the case of American shad, high outflow in one year is associated with an increased FMWT Index in that year, but high flow in one year is also associated with reduced FMWT Index in succeeding years. The net effect is essentially zero as the two relationships are basically mirror images and thus cancel each other out. Therefore, flow criteria for American shad are not supported by the best available science.

It is of interest that neither the DFG Report nor the State Water Board’s Flow Criteria Report contains flow criteria for striped bass. American shad have many similarities to striped bass – both are anadromous, both are introduced species from the Atlantic seaboard at about the same time, both use the estuary for spawning and nursery, bay shrimp is a primary food item for both. If flow recommendations for other species are sufficient for striped bass, why would separate criteria be needed for American shad?

X. The abundance indices do not suggest that California Bay Shrimp are doing poorly under existing D-1641 outflow requirements.

Kimmerer (2002a) and Kimmerer *et al.* (2009) are offered as support for an outflow-abundance relationship for bay shrimp, although neither reference mentions causal mechanisms for the relationship.¹⁴⁵ Nutrient and food web shifts explain the declines in bay shrimp as well or better than flows. Glibert (2010)¹⁴⁶ advances a plausible linkage between these shifts and the explosion in the populations of numerous invasive species, including *C. amurensis*. Catch data for bay shrimp from the Bay Study does not indicate that the species is doing poorly at current regulatory flow levels (D-1641 as amended).¹⁴⁷ Catch per tow over the 29 years of record have varied from 134 to 1,129 with a median value of about 517.¹⁴⁸ In wet years the indices tend to rise significantly.¹⁴⁹ Indices over the last four

¹⁴⁰ State Board Flow Policy at p. 82.

¹⁴¹ DFG Report at p. 81.

¹⁴² *Ibid.*

¹⁴³ *Ibid.*

¹⁴⁴ *Ibid.*

¹⁴⁵ DFG Report at 83, *citing*, Kimmerer WJ. 2002a. Effects of freshwater flow and abundance of estuarine organisms: Physical effects or trophic linkages? *Marine Ecology Progress Series* 243: 39-55 and Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuaries and Coasts* 32:375-389.

¹⁴⁶ Glibert P. 2010. Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco estuary, California. *Reviews in Fishery Science*.

¹⁴⁷ National Center for Ecological Analysis and Synthesis POD database found at <http://kn.b.ecoinformatics.org/knb/metacat?action=read&qformat=nceas&sessionid=0&docid=nceas.900.10&displaymodule=entity&entitytype=dataTable&entityindex=5>.

¹⁴⁸ National Center for Ecological Analysis and Synthesis POD database found at <http://kn.b.ecoinformatics.org/knb/metacat?action=read&qformat=nceas&sessionid=0&docid=nceas.900.10&displaymodule=entity&entitytype=dataTable&entityindex=5>.

¹⁴⁹ National Center for Ecological Analysis and Synthesis POD database found at <http://kn.b.ecoinformatics.org/knb/metacat?action=read&qformat=nceas&sessionid=0&docid=nceas.900.10&displaymodule=entity&entitytype=dataTable&entityindex=5>. Note the years 1984, 1986, 1998.

¹⁵⁰ DFG Report at pp. 86-87.

years have been at or above the median value.

Based on the above, the best available science does not support specific flow criteria for bay shrimp at this time.

XI. The most significant relationship is between zooplankton and diatom abundance.

E. affinis densities and persistence are purported to relate to March-May position of X2.¹⁵⁰ The DFG Report, like the State Water Board's Flow Criteria Report, does not state the causal mechanism for the relationship between *E. affinis* and X2. In fact, the relationship between *E. affinis* densities and diatoms is far stronger than the X2 relationship, as shown on Figure 14. The causal mechanism here is the fact that diatoms are a primary food source for *E. affinis*. In turn, while the relationship between diatoms and X2 is very weak, the relationship between diatoms and ammonia/um is very strong. A robust literature exists (e.g., Dugdale *et al.* 2007, Glibert *in press*)¹⁵¹ explains why ammonia/um is likely to suppress diatoms, which in turn suppresses *E. affinis* production.

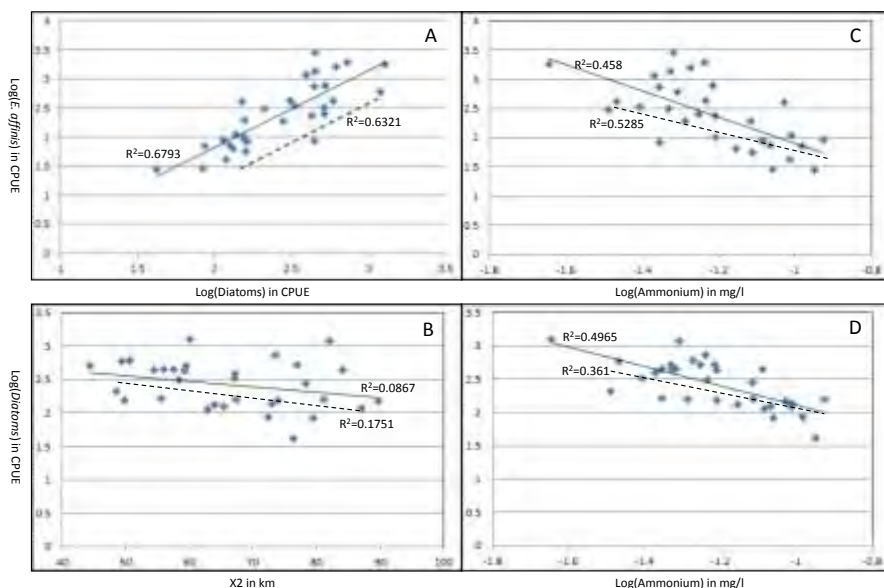


Figure 12. *Eurytemora affinis* and diatom densities compared to X2 and ammonium concentrations. Diatom and *E. affinis* densities in CPUE. Ammonium units in mg/l. A. Log(*E. affinis* density) v. Log(diatom density). B. Log(*E. affinis* density) v. Log(ammonium concentration). C. Log(diatom density) v. X2. D. Log(diatom density) v. Log(ammonium concentration). Solid lines are 1975-2006. Dashed lines are 1988-2006 (post-*C. amurensis*). Density data from NCEAS POD zooplankton database. X2 locations from DAYFLOW. Ammonium concentrations are the average of Stations D4, D6, D7, and D8 (Sacramento River above Point Sacramento, Suisun Bay at Middle Point, Grizzly Bay, and Martinez at Bulls Head).

XII. The abundance indices do not suggest that Sacramento splittail are doing poorly under existing D-1641 outflow requirements.

The DFG Report mentions splittail are a species of special concern to DFG and under review as a candidate species for protection under the federal Endangered Species Act. Now that the U.S. Fish and

¹⁵¹ Dugdale R, Wilkerson F, Hogue V, Marchi A. 2007. The role of ammonium and nitrate in spring bloom

¹⁵⁰ DFG Report at pp. 86-87.

¹⁵¹ Dugdale R, Wilkerson F, Hogue V, Marchi A. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. *Estuarine and Coastal Shelf Science* 73:17-29; Glibert P. 2010. Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco estuary, California. *Reviews in Fishery Science*.

Wildlife Service published its 12-month finding on the petition to list splittail and has found that its listing is not warranted at this time, the DFG Report should exclude the reference to the splittail being a candidate species.¹⁵²

The DFG Report describes the need for adequate flows to achieve inundation of floodplain habitat in the Yolo Bypass in above-normal and wet years. The science supports this general finding. It may be useful to review some background information on splittail that is not mentioned in its life history within the draft report.

Splittail are very fecund, with each female producing up to 150,000 eggs (Feyrer and Baxter 1998).¹⁵³ Splittail spawning occurs over flooded vegetation in tidal freshwater and brackish water habitats of estuarine marshes and sloughs and slow-moving, shallow reaches of large rivers (Sommer *et al.* 2007).¹⁵⁴ The Yolo and Sutter Bypasses, Butte Creek, Butte Sink, and Cosumnes River floodplains serve as important splittail spawning and early rearing habitat (Sommer *et al.* 1997),¹⁵⁵ as they approximate the large, open, shallow water areas in which splittail prefer to spawn. In wet, high flow years when these areas tend to flood, splittail abundance can increase dramatically. The years 1998 and 2005 had particularly high abundances following multiple dry years when abundance was reduced.

Survey data other than the FMWT have not shown declines in splittail abundance or distribution. The FMWT is not efficient at sampling splittail because it samples portions of the water column that are generally not used by splittail. For instance, the FMWT samples in open channels, whereas splittail are primarily found in shallower near-shore waters. Also, the FMWT does not sample the upstream range of splittail (Sommer *et al.* 2007).¹⁵⁶ Other survey data, such as the U.S. Fish and Wildlife Service's beach seine survey, have shown greater abundances of splittail than the FMWT, especially in wet years. The beach seine survey is designed to sample near-shore waters where splittail are typically found.

It is not unusual for splittail abundance to drop in dry years when inundation events do not occur. If one investigates alternative sampling data to the FMWT, which is inefficient at catching splittail (see Sommer *et al.* 2007), there is no evidence that splittail abundance has shown an unusual decline. Its life history is closely linked with flow events which inundate floodplains and riparian areas (Daniels and Moyle 1983; Sommer *et al.* 1997; Harrell and Sommer 2004; Moyle *et al.* 2004; Kratville 2008).¹⁵⁷ Even though their primary spawning activity is associated with wet years, some spawning takes place almost every year along the river edges and backwaters created by small increases in flow (Kratville 2008). When one focuses on surveys that sample floodplains and riparian areas, such as the Suisun Marsh Survey, the State Water Project salvage index, and the U.S. Fish and Wildlife Service's Beach Seine Survey (see Moyle *et*

¹⁵² U.S. Fish and Wildlife Service. 2010. Endangered and threatened wildlife and plants; 12-month finding on a petition to list the Sacramento Splittail as endangered or threatened. <http://www.fws.gov/policy/library/2010/2010-24871.pdf>.

¹⁵³ Feyrer F, Baxter R. 1998. Splittail fecundity and egg size. *California Fish and Game Bulletin* 84:119-126.

¹⁵⁴ Sommer T, Baxter R, Feyrer F. 2007. Splittail "delisting": A review of recent population trends and restoration activities. *American Fisheries Society Symposium* 53:25-38.

¹⁵⁵ Sommer T, Baxter R, Herbold B. 1997. Resilience of splittail in the Sacramento-San Joaquin estuary. *Transactions of the American Fisheries Society* 126:961-976.

¹⁵⁶ Sommer T, Baxter R, Feyrer F. 2007. Splittail "delisting": A review of recent population trends and restoration activities. *American Fisheries Society Symposium* 53:25-38.

¹⁵⁷ Daniels R, Moyle P. 1983. Life history of the splittail (Cyprinidae: *Pogonichthys macrolepidotus*) in the Sacramento-San Joaquin Estuary. *California Fish and Game Bulletin* 84:105-117; Sommer T, Baxter R, Herbold B. 1997. Resilience of splittail in the Sacramento-San Joaquin estuary. *Transactions of the American Fisheries Society* 126:961-976; Harrell W, Sommer T. 2003. Patterns of adult fish use on California's Yolo Bypass floodplain. In: Faber PM, editor. *California riparian systems: processes and floodplain management, ecology and restoration*. 2001 Riparian Habitat and Floodplains Conference Proceedings. Sacramento, CA: Riparian Habitat Joint Venture. p 88-93; Moyle P, Baxter R, Sommer T, Foin T, Matern S. 2004. Biology and population dynamics of Sacramento splittail (*Pogonichthys macrolepidotus*) in the San Francisco estuary: A review. *San Francisco Estuary and Watershed Science* 2(2); Kratville D. 2008. Semi-final species life history conceptual model - Sacramento splittail. Report to Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan.

al. 2004 for a summary of sampling data),¹⁵⁸ one finds that splittail abundance is not unusually low (see Sommer *et al.* 2007).¹⁵⁹

Historically, splittail reportedly were found throughout the central valley, extending as far north as Redding, CA, and as far south as the historic Tulare and Buena Vista Lakes (Moyle *et al.* 2004).¹⁶⁰ Except for these historic lakes, splittail are still distributed below dams throughout the San Joaquin River and Sacramento River watersheds, as well as the Bay-Delta (Kratville 2008).¹⁶¹ Sommer *et al.* (2007)¹⁶² Table 1 explains that splittail are still widely distributed and that their distribution has not changed substantially since the 1970s.

Several ecosystem restoration efforts are underway, including several CALFED-sponsored projects, CVPIA habitat restoration efforts, USACE restoration efforts on Prospect Island, CDWR restoration on Decker Island, and several other smaller efforts. Since 2003, additional restoration activities have been completed or are on the near-term horizon. Both the BDCP and the biological opinion the National Marine Fisheries Service prepared for the continued operation of the CVP and SWP contemplate changes to the Fremont Weir on the Sacramento River in order to increase both the area and frequency of Yolo Bypass seasonal inundation. A range of 17,000-20,000 acres will be seasonally inundated under these proposals, with benefits to splittail as well as salmonids.

The BDCP also anticipates restoring at least 5,000 acres in the Cache Creek complex, at least 1,500 acres in the Cosumnes/Mokelumne River regions, at least 2,100 acres in the western Delta, at least 5,000 acres in the southern Delta, and at least 1,400 acres in the eastern Delta. Much of these areas are within the distribution of splittail. While the Delta Stewardship Council's Delta Plan is not yet developed, it will be based on the Delta Visions Report (1/29/2008) which called for developing a more heterogeneous estuarine environment, including expanded seasonal and tidal wetlands. Based upon the ongoing and anticipated habitat restoration projects, splittail spawning and rearing habitat will be greatly expanded at a wide range of flows.

XIII. DFG fails to respond to science that supports a finding that the Bay-Delta ecosystem is suffering from significant water quality impairment, which has devastated the food web and overall health of the ecosystem.

DFG failed to fully evaluate the water quality that would be needed to support aquatic species in the Delta ecosystem. The legislative mandate required consideration of, "*the volume, quality, and timing of water necessary for the Delta ecosystem...*" (Emphasis added).¹⁶³ The best available science already supports establishing nutrient criteria as a more effective and efficient means to protect public trust resources than changing the flow criteria that already exist in D-1641.

While the DFG Report acknowledges the work of Dr. Glibert regarding the effect ammonia on ecosystem function, it fails to propose a biological objective.¹⁶⁴ DFG should have considered the complete body of work that establishes that the productivity of the food web is directly related to the ratio of nutrients (N:P)

¹⁵⁸ For summary of sampling data, See, Moyle P, Baxter R, Sommer T, Foin T, Matern S. 2004. Biology and population dynamics of Sacramento splittail (*Pogonichthys macrolepidotus*) in the San Francisco estuary: A review. *San Francisco Estuary and Watershed Science* 2(2).

¹⁵⁹ Sommer T, Baxter R, Feyrer F. 2007. Splittail "delisting": A review of recent population trends and restoration activities. *American Fisheries Society Symposium* 53:25–38.

¹⁶⁰ Moyle P, Baxter R, Sommer T, Foin T, Matern S. 2004. Biology and population dynamics of Sacramento splittail (*Pogonichthys macrolepidotus*) in the San Francisco estuary: A review. *San Francisco Estuary and Watershed Science* 2(2).

¹⁶¹ Kratville D. 2008. Semi-final species life history conceptual model - Sacramento splittail. Report to Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan.

¹⁶² Sommer T, Baxter R, Feyrer F. 2007. Splittail "delisting": A review of recent population trends and restoration activities. *American Fisheries Society Symposium* 53:25–38.

¹⁶³ Delta Reform Act, Water Code Section 85086(c)(1).

¹⁶⁴ DFG Report at p. 93.

in the environment. As described in detail below, there isn't just a single study by Dr. Glibert rather there is an entire library of information related to the Delta and other similar estuaries world-wide that link nutrients to primary productivity and fisheries abundance.

It is also worth noting an error in the DFG Report's findings, where it is indicated that the Sanitation District's ammonia discharge is not acutely or chronically toxic.¹⁶⁵ In fact, the District's ammonia discharge could be chronically toxic to larval Delta smelt,¹⁶⁶ and recent experiments have found that the discharge is causing chronic toxicity in the Sacramento River to invertebrate populations.¹⁶⁷

The DFG Report should be amended to be more consistent with DFG's position in its recent comment letter to the Central Valley Regional Water Quality Control Board ("Regional Board") regarding the tentative permit ("Tentative Permit") for the Sacramento Regional County Sanitation District ("Sanitation District") where DFG stated, "...ammonia loading in the Delta ecosystem may be inhibiting phytoplankton nitrogen uptake and that existing EPA criteria may not be protective of ammonia sensitive species in the Delta."¹⁶⁸ DFG recommended removal of nutrients from the Sanitation District's effluent to ensure protection of aquatic life and species."¹⁶⁹ DFG was not alone in its recommendation on the Sanitation District's permit, as others concurred stating:

Evidence, however points to discharge from the SRWP affecting the composition of the phytoplankton of the Delta waterways, contributing to harmful algal blooms in the delta, and influencing the aquatic plant community within the Delta. It is time to make the SWTP a key component of the overall Delta solution by bringing current treatment into the 21st Century.¹⁷⁰

Cliff Dahm, Lead Scientist
Delta Stewardship Council

We believe that the current discharge from the Sacramento Regional Wastewater Treatment Plant ("SRWTP") discharge may be impairing the aquatic life beneficial use in Suisun Bay, and possibly upstream, by having a detrimental effect on primary productivity and phytoplankton species composition. SRWTP is the largest publicly-owned treatment plant in the Delta and is estimated to contribute up to 90 percent of the annual ammonia load to the Sacramento River (Jassby 2008)...In conclusion, we urge Region 5 to take all necessary actions to assure that Suisun Bay beneficial uses are fully protected.¹⁷¹

Bruce H. Wolfe, Executive Officer
San Francisco Bay Regional Water Quality Control Board

¹⁶⁵ DFG Report at pp. 92-93.

¹⁶⁶ Werner I, Deanovic L, Stillway M, Markiewicz D. 2009. Acute Toxicity of Ammonium and Wastewater Treatment Effluent- Associated Contaminants on Delta Smelt- 2009. Final report to the State Water Resource Control Board.

¹⁶⁷ Central Valley Regional Water Control Board. 2010. Nutrient Concentrations and Biological Effects in the Sacramento- San Joaquin Delta. Report dated July 2010; The S. Lu M, The FC, Lesmeister S, Werner I, Krause J, Deanovic L. 2008. Final report toxic effects of surface water in the upper San Francisco Estuary on *Eurytemora affinis*. Report to San Luis and Delta Mendota Water Authority.

¹⁶⁸ Letter from Carl Wilcox, DFG, to Kenneth Landau, Regional Board, Re: Response to the proposed NPDES permit renewal for the Sacramento Regional County Sanitation District Sacramento Regional Wastewater Treatment Plant, October 7, 2010, pp. 2-3.

¹⁶⁹ *Ibid.*

¹⁷⁰ Letter to Kathy Harder, Regional Board, from Philip L. Isenberg, Delta Stewardship Council, Transmitting conclusion of Lead Scientist, Cliff Dahm, Re: Proposed Permit Order #0077682, concerning the Sacramento County Regional Sanitation District Wastewater Treatment Plant Discharge, October 7, 2010.

¹⁷¹ Letter to Kathy Harder, Central Valley Regional Board, from Bruce H. Wolfe, San Francisco Regional Board, Subject: Comments on "Issue Paper - Aquatic Life and Wildlife Preservation Related Issues - Proposed NPDES Permit Renewal for Sacramento Regional County Sanitation District Sacramento Regional Wastewater Treatment Plant," June 4, 2010.

The Sacramento Regional Wastewater Treatment Plant is one of the largest wastewater dischargers in the estuary. And it is one of the declining number of wastewater treatment plants that has not yet been required to upgrade to more advanced forms of treatment that would eliminate or substantially reduce levels of ammonium and other pollutants from entering the Sacramento River... There is growing evidence that ammonium inhibits the production of pelagic organisms, a critical food supply of native fisheries. We encourage you to review this evidence and factor it into your decision-making process.¹⁷²

Leo Winternitz, Delta Project Director
The Nature Conservancy

It is imperative that discharges of wastewater into this sensitive river reach in an estuary that is experiencing ecosystem collapse be subject to the most rigorous regulatory treatment standards. Inexplicably, for many years, Sacramento Regional's wastewater plant has been exempted from requirements routinely applied to other wastewater treatment facilities in the region... For too long, Sacramento regional has externalized the adverse costs of wastewater treatment to a degraded environment. For too long, the citizens of Sacramento have enjoyed low utility bills subsidized by the degradation of public trust assets owned in common by all Californians. Discharging pollutants into waters of the nation is a privilege, not a right. It is time for Sacramento residents to pay their fair share for enjoying that privilege.¹⁷³

Bill Jennings, Executive Director
California Sportfishing Protection Alliance

Increased loading of ammonia from the SRWTP has occurred in the Sacramento River and the Delta since 1995 (Jassby 2003). Ammonia loading in the Delta may be inhibiting nitrogen uptake by phytoplankton throughout delta smelt's habitat, reducing energy availability at the base of the Delta food web (Dugdale 2007; Jassby 2008; Glibert 2010). Recent studies suggest that existing EPA criteria when converted to unionized ammonia may not be protective of ammonia sensitive species in the Delta, specifically delta smelt, both acutely when pH equals or exceeds 8.3 and chronically depending on pH, temperature and conductivity (Werner 2009).¹⁷⁴

Dan Castleberry, Field Supervisor
United States Fish and Wildlife Service

DFG should also amend its Report to be more consistent with the Regional Board. In the Sanitation District's Tentative Permit, the Regional Board concluded that the Sanitation District is a major source of ammonia loading into the Delta, having a significant effect on the food-web, as well as causing chronic toxicity in the Sacramento River. The Regional Board's summary of conclusions includes, but are not limited to, the following:

- ...The [Sanitation District's] discharge accounts for over 60% of all the municipal wastewater discharged to the Delta.
- Scientific experts have expressed concern that ammonia levels in the Sacramento River and Delta could be chronically toxic to smelt.

¹⁷² Letter to Kathy Harder, Regional Board, from Leo Winternitz, The Nature Conservancy, June 1, 2010.

¹⁷³ Letter to Kathy Harder, et. al., from Bill Jennings, California Sportfishing Protection Alliance, re: Renewal of Waste Discharge Requirements (NPDES No. CA0077682) for Sacramento Regional County Sanitation District, Sacramento Regional Wastewater Treatment Plant, Sacramento County, October 8, 2010.

¹⁷⁴ Letter to Kathy Harder, from Dan Castleberry, FWS, Re: Comments on the NPDES Permit Renewal Issues: Aquatic Life and Wildlife Preservation, Sacramento Regional County Sanitation District, Sacramento Regional Wastewater Treatment Plant, June 15, 2010.

- Recent experiments found that the ammonia in the District's discharge is causing chronic toxicity in the Sacramento River for about 30 miles downstream of the discharge to *Eurytemora affinis* and *Pseudodiaptomas forbesi*, both invertebrate species that are important forage organisms for larval fish.
- The District's discharge is a significant source of ammonia in Suisun Bay and is suppressing Diatom production in Suisun Bay, reducing a significant part of the food supply for Delta Smelt and other fish. The total dissolved nitrogen concentrations between the District's discharge and an area two-miles upstream of Suisun Bay are stable, indicating there are no large nitrogen or ammonia sources or sinks between the two locations.
- The District's discharge changes the predominant form of nitrogen in the Sacramento River from nitrate to ammonia, which is suspected of changing the phytoplankton population in the River from Diatoms to smaller, less nutritious flagellates and bluegreen algae, which could negatively impact fish populations.
- Discharges of pollutants from the District contribute to the cumulative effects of multiple physical and chemical stressors to the Sacramento River and the Delta. The existing secondary treatment of the District's discharge is not sufficient to protect aquatic life, or human contacting or ingesting the wastewater.
- The District's discharge of domestic sewage contains 14 tons per day of ammonia, and is the major source of ammonia to the Sacramento River and the Delta. The average annual ammonia concentration in the River increased 11.5-fold in the River below the District's discharge.¹⁷⁵

The Regional Board further concluded that:

Not improving treatment by the District's facility will result in continued discharge of harmful levels of non-toxic and toxic pollutants to the Sacramento River and Delta and may:

- Natively impact food supply for Delta fish
- Negatively impact resident and migratory fish through toxicity and reduced food sources
- Negatively impact commercial and recreational fishing
- Negatively impact the ability to pump water from the Delta for drinking water and agricultural irrigation supplies
- Result in social and economic impacts caused by people getting sick from contacting the River water.¹⁷⁶

The DFG Report should have considered the science outlined in the Regional Board's Tentative Permit, and as further described below:

a. The Sanitation District is a major source of ammonia/um to the Bay-Delta.

The Regional Water Quality Control Board's Tentative Order ("Tentative Order") states that a "consensus of scientific experts concluded the SRWTP is a major source of ammonia/um to the Delta." Tentative Order, F-55. The Plant currently disposes an estimated *10,000,000 pounds of ammonia/um* into the Sacramento River each year, or about 14 tons per day and this amount has been increasing over time (*See*

¹⁷⁵ Summary of Tentative NPDES Permit, California Regional Water Quality Control Board, 18 October 2010.

¹⁷⁶ *Ibid.*

Figure 1).¹⁷⁷ The extensive data supporting this conclusion includes data collected by the Central Valley and San Francisco Regional Boards. Tentative Order, Att. K at K-5, K-6.

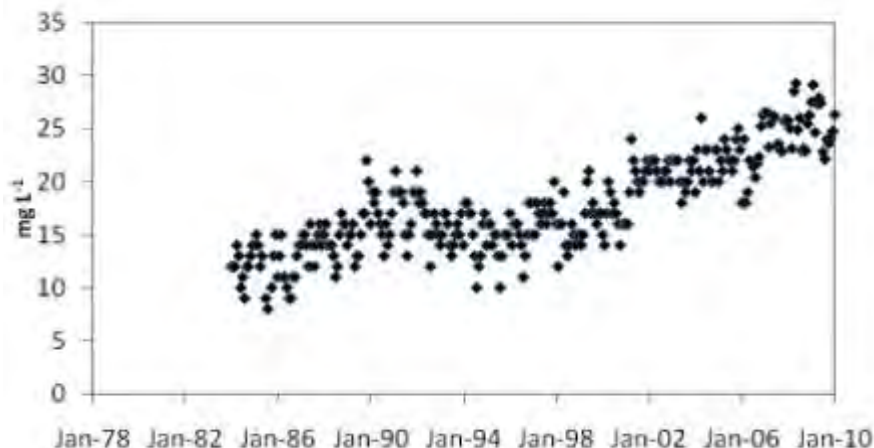


Figure 14 Change in effluent ammonium concentration (mg L^{-1}) over time, based on data reported to the Regional Board. Note that although the Treatment Plant came on line in 1982, data are available from 1984. All data are monthly averages.

Modeling by Resource Management Associates (2009) also indicates that changes in nutrient concentrations due to the Treatment Plant's nutrient discharges can be seen along the Sacramento River corridor to Suisun Bay, as well as at Jersey Point, Potato Point and Georgiana Slough.¹⁷⁸ Dr. Patricia Glibert of the University of Maryland has found that changes in ammonium concentration in the Treatment Plant's effluent are highly correlated with changes in ammonium concentrations in the Sacramento River at Hood and with concentrations in Suisun Bay.¹⁷⁹ Dr. Carol Kendall of the United States Geological Survey determined that nutrients and organic matter downstream of the Treatment Plant are isotopically distinguishable from upstream Sacramento River and Cache Slough tributary nutrients. The differences become even more distinctive further downstream as more ammonium is nitrified; the Treatment Plant's ammonium is distinguishable from other sources of ammonium all the way to Suisun Bay.¹⁸⁰ Mass balance calculations with the available chemical and isotopic data from the Cache Slough tributaries show that the confluence area between the sloughs and the mainstem river at Rio Vista acts mainly as a sink, not a source, of slough-derived nutrients and organic matter to sites downstream of Rio Vista.¹⁸¹ Parker *et al.* (2010b) were also able to track ammonium from Treatment Plant discharges along the entire Sacramento River transect to Suisun Bay.¹⁸²

¹⁷⁷ 14 tons x 2000 lbs. x 365 day = 10,220,000 lbs./year. That could double to more than **20 million pounds**, if the interim daily limit in the Tentative Order is not reduced and other interim measures are not required, as outlined elsewhere in these comments.

¹⁷⁸ Resource Management Associates. 2009. Modeling the fate and transport of ammonia using DSM2-QUAL, Draft final report, October 2009. Prepared for State Water Contractors.

¹⁷⁹ Glibert, P., 2010a. "Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco Estuary, California," *Reviews in Fisheries Science*.

¹⁸⁰ Kendall, C., Silva, S.R., Young, M.B., Guerin, M., Kraus, T., and Parker, A., 2010. Stable isotope tracing of nutrient and organic matter sources and biogeochemical cycling in the Sacramento River, Delta, and Northern Bay. U.S. Geological Survey Open-File Report 2010-XX, preliminary draft for colleague review, 52 pages; Kendall, C. 2010a. Causes of seasonal and spatial variation in water chemistry in the Sacramento River, Delta, and Eastern San Francisco Bay and their effects on chlorophyll levels. Oral Presentation at 6th Biennial Bay-Delta Science Conference, Sacramento, CA. September 27-29, 2010.

¹⁸¹ *Ibid.*

¹⁸² Parker, A.E., Dugdale, R.C., Wilkerson, F., Marchi, A. 2010b. Biogeochemical Processing of anthropogenic ammonium in the Sacramento River and the northern San Francisco Estuary: consequences for Pelagic Organism

b. The ammonia discharge is toxic to copepods and fish and does not meet the most current EPA aquatic life criteria for ammonia.

The Tentative Order found that the Treatment Plant discharges 14 tons of ammonia/um discharged every day which has the “reasonable potential to cause or contribute to an exceedance of the Basin Plan’s narrative toxicity objective in the receiving water.” Att. F. at F-54. Referencing studies by Werner, Teh, and Johnson, the Tentative Order reasons that “[r]ecent studies suggest that ammonia at ambient concentrations in the Sacramento River, Delta and Suisun Bay may be acutely toxic to the native *Pseudodiaptomus forbesi* (copepod).” Tentative, Order, Att. F at F-54 and Att. K at K-2. The Tentative Order also states, “[r]egardless of whether ammonia is directly or indirectly contributing to the [pelagic organism decline], ammonia is shown to affect adult *Pseudodiaptomus forbesi* reproduction at concentrations greater than or equal to 0.79 mg L⁻¹. And nauplii and juvenile *Pseudodiaptomus forbesi* are affected at ammonia concentrations greater than or equal to 0.36 mg L⁻¹. These ammonia concentrations can be found downstream of the discharge. The beneficial use protection extends to all aquatic life and is not limited to pelagic organisms.” Tentative Order, Att. F at F-55.

Ammonia/um concentrations above 0.36 mg L⁻¹ were measured by the Regional Board all the way to Isleton, 27 miles downstream of the Treatment Plant. In fact, ammonia/um exceeded 0.36 mg L⁻¹ in 44% of the samples collected at stations between Hood and Isleton on the Sacramento River in 2009-2010.¹⁸³ The Tentative Order notes these toxic impacts are real and provides ample support for the ammonia/um effluent limits and nutrient removal required by the Tentative Order, regardless of the other effects of the discharge.

EPA’s 2009 Ammonia Criteria Update relies on current science to define updated ammonia criteria to protect aquatic life. See “Draft 2009 Update Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater” in December 2009. Att. F at F-55, Att. K at K-3, K-4. Viewing the Treatment Plant’s discharge through the lens of these most current criteria, the serious adverse effect on beneficial use of the proposed discharge is clear, as the Treatment Plant’s discharge regularly exceeds those criteria. In fact, the EPA draft ammonia criteria would have been exceeded 29% of the time in 2008 at R3 downstream of the Treatment Plant and 16% of the time from January 2007 to April 2010.¹⁸⁴

It has been further established that endangered Delta smelt spawn just downstream of the Sanitation District’s outfall. As the United States Fish & Wildlife Service noted in its biological opinion regarding the threatened Delta smelt, the Sanitation District’s “discharge places it upstream of the confluence of Cache Slough and the mainstem of the Sacramento River, a location just upstream of where Delta smelt have been observed to congregate in recent years during the spawning season.”¹⁸⁵ This recognized the “potential for exposure of a substantial fraction of Delta smelt spawners to elevated ammonia levels” that have repeatedly been found to be toxic.¹⁸⁶

There is substantial additional support documenting the toxic impacts of ammonia/um. For example, Parker *et al.* (2010a) conducted parallel tests with ammonium chloride and the Sanitation District’s

Decline species. Oral Presentation at 6th Biennial Bay-Delta Science Conference, Sacramento, CA. September 27-29, 2010.

¹⁸³ Data provided by Chris Foe, Central Valley Regional Water Quality Control Board, collected between March 2009 and February 2010.

¹⁸⁴ These values differ from those provided in the Water Agencies’ Comments on Aquatic Life and Wildlife Preservation Issues Concerning the Sacramento Regional Wastewater Treatment Plant NPDES Permit Renewal (June 1, 2010) at 22 because the data provided by the Regional Water Board at the time of the previous comments only included monitoring through 7/22/2008. The calculations in these comments are based on a data file provided by Kathy Harder, Regional Board, entitled “Compilation of SRCSD Effluent and Receiving Water Concentration Data,” dated July 13, 2010.

¹⁸⁵ USFWS. 2008. Biological opinion on the proposed coordinated operations of the Central Valley Water Project (“CVP”) and the State Water Project (“SWP”), December 15, 2008 (“Delta Smelt BiOp”) at p. 245.

¹⁸⁶ *Ibid.*

effluent on primary production and phytoplankton nitrogen uptake.¹⁸⁷ Compared to controls, primary production and ammonium uptake rates were reduced 20 to 36% and phytoplankton nitrate uptake was reduced 80% at effluent ammonium concentrations greater than 8 $\mu\text{mol N L}^{-1}$, equivalent to a river:effluent dilution greater than 200:1. This dilution rate greatly exceeds actual river:effluent dilutions. According to the Regional Board's "NPDES Permit Renewal Issues: Drinking Water Supply and Public Health" paper dated December 14, 2009, flow ratios nearing 14:1 are not uncommon during dry years under the existing plant capacity. In other words, during dry years, approximately 7% of the river can be effluent.

c. The ammonium and other nutrients are adversely altering the food web that supports aquatic life in the Sacramento River and Bay-Delta

A significant shift in the pelagic food web has occurred in the Bay-Delta; this has been identified as a significant factor in the well-documented Pelagic Organism Decline (POD). Primary productivity and phytoplankton biomass in the Bay-Delta are among the lowest of all estuaries studied and dropped even lower in the 1980s, and declines in several zooplankton species have followed the chlorophyll ("chl-*a*") declines. Research indicates that Delta-wide chl-*a* levels are now low enough to limit zooplankton abundance¹⁸⁸, and zooplankton are an essential prey item for endangered fish species in the Bay-Delta, including the Delta smelt¹⁸⁹.

The Bay-Delta's algal species composition has shifted from diatoms to flagellates, cryptophytes and cyanobacteria, which are a lower food quality, and to invasive macrophytes such as *Egeria densa*. See Water Agencies' June 1 Comments at 13. The shift from diatoms to smaller celled phytoplankton results in a less efficient food web. Cloern and Dufford state, "[s]ize is important because many metazoan consumers, such as calanoid copepods, cannot capture small particles, including the nutritionally-rich nanoflagellates (Fenchel 1988)."¹⁹⁰ Recent studies in the San Francisco Estuary's low salinity zone by Slaughter and Kimmerer (2010) observed lower reproductive rates and lower growth rates of the copepod, *Acartia* sp. in the low salinity zone compared to taxa in other areas of the estuary. They conclude that "[t]he combination of low primary production, and the long and inefficient food web have likely contributed to the declines of pelagic fish."¹⁹¹ Cloern and Dufford (2005) also state, "[t]he efficiency of energy transfer from phytoplankton to consumers and ultimate production at upper trophic levels vary with algal species composition: diatom-dominated marine upwelling systems sustain 50 times more fish biomass per unit of phytoplankton biomass than cyanobacteria-dominated lakes (Brett & Müller-Navarra 1997)."¹⁹²

Substantial field data have demonstrated the increasing decline of the phytoplankton in the Delta and Suisun Bay. For example, Wilkerson *et al* (2010) categorized three different phytoplankton responses to increasing ammonium concentrations:

¹⁸⁷ Parker, A.E., A.M. Marchi, J.Drexel-Davidson, R.C. Dugdale, and F.P. Wilkerson. 2010a. "Effect of ammonium and wastewater effluent on riverine phytoplankton in the Sacramento River, CA. Final Report to the State Water Resources Control Board.

¹⁸⁸ Müller-Solger, A., A.D. Jassby and D.C. Müller-Navarra. 2002. Nutritional quality of food resources for zooplankton (*Daphnia*) in a tidal freshwater system (Sacramento-San Joaquin River Delta). *Limnol Oceanogr* 47(5):1468-1476.

¹⁸⁹ Sommer, T, C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga and K. Souza. 2007. The Collapse of Pelagic Fishes in the Upper San Francisco Estuary. *Fisheries* 32(6):270-277; Winder, M. and A.D. Jassby. In press. Shifts in zooplankton community structure: Implications for food web processes in the Upper San Francisco Estuary. *Estuaries and Coasts*. DOI 10.1007/s12237-010-9342-x.

¹⁹⁰ Cloern, J.E., and R. Dufford. 2005. Phytoplankton community ecology: principles applied in San Francisco Bay. *Mar. Ecol. Prog. Ser.* 285:11-28.

¹⁹¹ Slaughter, A. and W. Kimmerer. 2010. Abundance, composition, feeding, and reproductive rates of key copepod species in the food-limited Low Salinity Zone of the San Francisco Estuary. Poster Presentation at the 6th Biennial Bay-Delta Science Conference, Sacramento, CA, September 27-29, 2010.

¹⁹² Cloern and Dufford, 2005, *supra*.

- Type I: healthy phytoplankton were able to drawdown all available dissolved inorganic nitrogen and accumulate chlorophyll in 2-3 days;
- Type II: phytoplankton were able to drawdown nutrients, but the chlorophyll accumulation was delayed in time; and
- Type III: phytoplankton were unable to drawdown the nitrate and accumulate chlorophyll by 6 days.¹⁹³

In repeated phytoplankton grow out experiments from Suisun Bay and the River, almost none had healthy Type I responses. Instead, samples from Suisun Bay typically showed Type II responses while samples from the Sacramento River at Rio Vista, where ambient ammonium concentrations are higher, all exhibited Type III responses. In addition, Parker *et al* (2010b) observed predictable and reproducible patterns in phytoplankton rates in response to ammonium concentrations in Sacramento River transects in 2008 and 2009.¹⁹⁴ Increases in nutrient loading and changes in nutrient ratios over time are a primary driver of these observed changes in the food web.¹⁹⁵

d. Ammonia is inhibiting nitrogen uptake by diatoms in the Bay-Delta.

The fact that ammonium loading inhibits nitrogen uptake by phytoplankton is a phenomenon long established in the scientific community in research done over many decades and in a variety of systems. It continues to be demonstrated in ongoing research (Wilkerson *et al.* 2006, Dugdale *et al.* 2007, Glibert 2010a).¹⁹⁶ New data collected was also collected in Suisun Bay in the spring of 2010 by the San Francisco Regional Board and by the Dugdale Lab at San Francisco State University's Romberg Tiburon Center.¹⁹⁷

Accordingly, the DFG Report should reference the ongoing studies and the decades of scientific research that confirm that ammonium suppresses algae productivity, a phenomenon which was first observed by researchers as far back as the 1930's.¹⁹⁸ Some of the early field demonstrations were by MacIsaac and Dugdale (1969, 1972),¹⁹⁹ followed by research in the Chesapeake Bay by McCarthy *et al* (1975).²⁰⁰ Lomas and Glibert (1999a) describe the threshold for inhibiting nitrate uptake at approximately 1 $\mu\text{mol L}^{-1}$ (0.014 mg L⁻¹), many orders of magnitude below the level of the discharge from the Treatment Plant.^{201,202}

Ammonium suppression of nitrate uptake when both nutrients are in ample supply should not be confused with the preferential use of ammonium by phytoplankton when nitrogen is limiting. When nitrogen is limiting, phytoplankton will use ammonium preferentially because it requires less energy to use

¹⁹³ Wilkerson, F., R. Dugdale, A. Marchi, and A. Parker. 2010. "Different response types of phytoplankton to changing nutrient regimes in SF Bay/Delta: Bottom up effects of ammonium and nitrate." Oral Presentation at 6th Biennial Bay-Delta Science Conference, Sacramento, CA, September 27-29, 2010.

¹⁹⁴ Parker *et al.*, 2010b, *supra*.

¹⁹⁵ Glibert, 2010a, *supra*; Parker, *et al.*, 2010a, *supra*; Parker, *et al.*, 2010b, *supra*; Wilkerson, *et al.*, 2010, *supra*.

¹⁹⁶ Marchi, 2010, *supra*.

¹⁹⁷ Marchi, A. 2010. "Spring 2010 phytoplankton blooms in Northern San Francisco Estuary: influences of climate and nutrients." Oral Presentation at 6th Biennial Bay-Delta Science Conference, Sacramento, CA, Sept. 27-29, 2010.

¹⁹⁸ See, *e.g.*, Ludwig, C.A. 1938. The availability of different forms of nitrogen to a green alga (*Chlorella*) *Am.J.Bot.* 25:448-458; Harvey, H.W. 1953, Synthesis of Organic Nitrogen and Chlorophyll by *Nitzschia Closterium*. *J. Mar.Biol. Res. Assoc. U.K.* 31:477-487.

¹⁹⁹ MacIsaac, J.J. and R.C. Dugdale, 1969. The kinetics of nitrate and ammonium uptake by natural populations of marine phytoplankton. *Deep-Sea Res.* 16:45-67; MacIsaac, J.J. and R.C. Dugdale, 1972. Interactions of light and inorganic nitrogen controlling nitrogen uptake in the sea. *Deep-Sea Res.* 19:209-232.

²⁰⁰ McCarthy, J.J., W.R. Taylor and J.L. Taft, 1975. The dynamics of nitrogen and phosphorous cycling in the open water of the Chesapeake Way. In: T.M. Church (ed.) *Marine Chemistry in the Coastal Environment*. American Chemical Society Symposium Series 18. Washington D.C., pp. 664-681.

²⁰¹ Lomas, M.W. and P.M. Glibert. 1999a. Interactions between NH_4 and NO_3 uptake and assimilation: comparison of diatoms and dinoflagellates at several growth temperatures. *Marine Biology* 133:541-551

²⁰² The current average discharge concentration is 24 mg L⁻¹ NH_4 which equates to 1,713 $\mu\text{mol L}^{-1}$.

ammonium than nitrate. When both nutrients are in ample supply, the phytoplankton cells must cope with the excess; and in doing so, the phytoplankton metabolism is altered away from an ability to assimilate nitrate and thus their total primary productivity is suppressed. This is particularly problematic for the Bay-Delta as it is already a comparatively low producing estuary.²⁰³ Laboratory data indicate that Delta-wide chl-*a* levels are now low enough to limit zooplankton abundance.²⁰⁴

e. The nutrient discharge is impacting the food web in the Sacramento River and Bay-Delta by causing a shift in algal communities by changing the nutrient ratios to favor harmful, invasive species.

The Tentative Order notes in Attachment F that “[d]ownstream of the discharge point, ammonia may be a cause in the shift of the aquatic community from diatoms to smaller phytoplankton species that are less desirable as food species.” Tentative Permit, Att. F at F-55. The Tentative Order references some of the recent research in this area, including that of Dr. Dugdale, Dr. Glibert, and Dr. Lehman (*see* Attachment K at K-6 and K-7).

The Treatment Plant’s discharge has adversely impacted aquatic life in the River and Bay-Delta by increasing the ratio of nitrogen to phosphorus in the receiving water which triggers the impacts to the food web on which aquatic life depends. These impacts have contributed to the dramatic decline in pelagic organisms, directly impairing the protected beneficial uses of the Bay-Delta waters. The impacts on the food web are due to the fact that the ongoing discharge degrades water quality by changing the ratio between dissolved inorganic nitrogen and phosphorus in the River downstream of the Treatment Plant – the “DIN:DIP” ratio – as well as the Nitrogen (N) to Phosphorus (P) ratio – the (“N:P”) ratio. These ratios are known to have profound influences on food webs (Sterner and Elser 2002).²⁰⁵ Sterner and Elser (2002), state that, “Stoichiometry can either constrain trophic cascades by diminishing the chances of success of key species, or be a critical aspect of spectacular trophic cascades with large shifts in primary producer species and major shifts in ecosystem nutrient cycling.” A low ratio is generally considered to cause nitrogen limitation, whereas a high ratio is generally considered to cause phosphorus limitation. When the N:P ratio nears 16:1 on a molar basis, it is recognized as the Redfield ratio, based on the classical observations of Redfield (1934; 1958)²⁰⁶. (The Redfield ratio does not, however, distinguish the importance of different forms of nitrogen, *i.e.*, whether that nitrogen is in the form of ammonium or nitrate.)

Historical data indicate that the N:P ratio of Treatment Plant effluent has increased significantly over time due to the significant increase in the ammonia/um loading in the discharge, and corresponding declines in phosphorus, most likely because of decreases in phosphates in laundry detergent (Van Nieuwenhuyse 2007, Glibert 2010a).²⁰⁷ The N:P effluent ratios have been above stoichiometric proportions since the early to mid-1990s, suggesting a tendency towards increasing phosphorus limitation.

Glibert has examined the loadings from the Treatment Plant, the shifting nutrient ratios, and the composition of the base of the food web and found several significant trends.²⁰⁸ Specifically, Glibert (2010a) reports that there has been a measureable change in the N:P ratio in the Bay-Delta, an increase in total N loading, a decrease in total P loading, and a change in the dominant form of nitrogen from nitrate

²⁰³ Jassby, A.D., J.E. Cloern and B.E. Cole. 2002. Annual primary production: Patterns and mechanisms of change in a nutrient-rich tidal ecosystem. *Limnol. Oceanogr.*, 47(3): 698–712.

²⁰⁴ Müller-Solger, *et al*, 2002, *supra*.

²⁰⁵ Sterner, R.W. and J.J. Elser. 2002. Ecological stoichiometry: The biology of elements from molecules to the biosphere. Princeton University Press, Princeton, N.J.

²⁰⁶ Redfield, A.C. 1934. On the proportions of organic derivatives in sea water and their relation to the composition of plankton. Reprinted from *James Johnstone Memorial Volume*, Liverpool University Press, Liverpool. 176-192; Redfield, A.C. 1958. The biological control of chemical factors in the environment. Reprinted from *The American Scientist*. 46(3):205-221.

²⁰⁷ Van Nieuwenhuyse, E. 2007. Response of summer chlorophyll concentration to reduced total phosphorus concentration in the Rhine River (Netherlands) and the Sacramento-San Joaquin Delta (California, USA). *Can. J. Fish. Aquat. Sci.*, 64:1529-1542; and Glibert, 2010a, *supra*.

²⁰⁸ Glibert, 2010a, *supra*.

to ammonium. Glibert found that the variation in these nutrient concentrations and ratios is highly correlated to variations in the nutrient composition of the Treatment Plant's discharges. These nutrient variations are in turn related to variations in the base of the food web, primarily the composition of phytoplankton (Glibert 2010b)²⁰⁹, to variations in the composition of zooplankton, and to variations in the abundance of several fish species. Thus, changes in Delta smelt and several other fish species' abundance are ultimately related to changes in ammonium load from wastewater discharge in the upper Sacramento River.

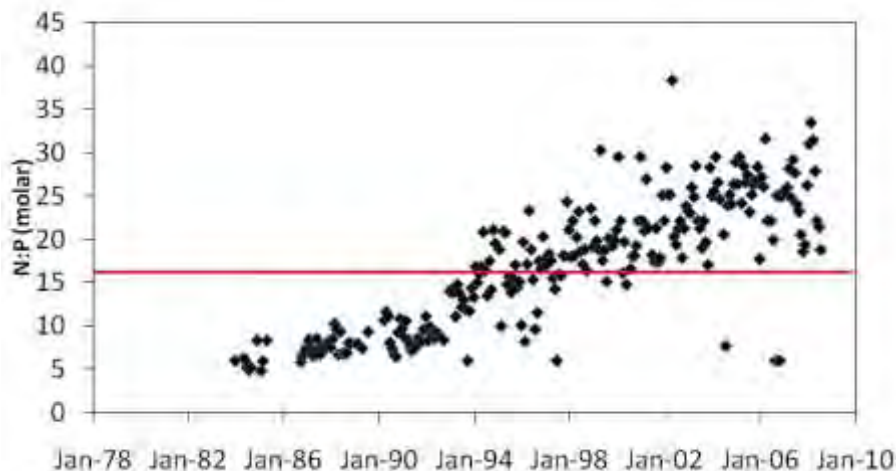


Figure 14 Change in molar ratio of nitrogen to phosphorus in Treatment Plant discharge over time. This ratio is calculated from nitrogen based on TKN and phosphorus from TP, based on data reported to the Regional Board. Note that although the Treatment Plant came on line in 1982, data are available from 1984. All data are monthly averages. The horizontal line is the “Redfield” ratio.

The data also indicate that the algal community that compose the Delta food web has been shifting at the same time that the nutrient ratios have been changing (Glibert 2010a,b).²¹⁰ The shift is seen both in the recent increase in annual blooms of *Microcystis*, and in the shift in the algal composition in the Bay-Delta from diatoms that are nutritious to the zooplankton that support the pelagic food web including the threatened Delta smelt,²¹¹ to smaller and lower quality species such as flagellates, cryptophytes and cyanobacteria and to invasive macrophytes such as *Egeria densa*.²¹² The shift away from diatoms, which disrupts ecosystem function, is well documented in the literature in general, and in research specifically

²⁰⁹ Glibert, P. 2010b. Changes in the quality and quantity of nutrients over time and the relationships with changes in phytoplankton composition. Oral Presentation at 6th Biennial Bay-Delta Science Conference, Sacramento, CA, September 27-29, 2010.

²¹⁰ Glibert, 2010a, *supra*; Glibert, 2010b, *supra*.

²¹¹ The Tentative Permit stated that “[d]iatoms are assumed to be more nutritious to primary consumers like zooplankton than flagellates and bluegreen algae.” Att. K at K-7. Respectfully, this is much more than an assumption. Numerous studies have found that diatoms support the pelagic food web.

²¹² Lehman, P. W. 2000. The influence of climate on phytoplankton community biomass in San Francisco Bay Estuary. *Limnol. Oceanogr.* 45: 580–590; Lehman, P. W., G. Boyer, C. Hall, S. Waller and K. Gehrts. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. *Hydrobiologia* 541:87-99; Lehman, P.W., S.J. The, G.L. Boyer, M.L. Nobriga, E. Bass, and C. Hogle. 2010. Initial impacts of *Microcystis aeruginosa* blooms on the aquatic food web in the San Francisco Estuary. *Hydrobiologia* 637:229-248; Jassby *et al.*, 2002, *supra*; Glibert, *supra*; Sommer, *et al.*, 2007, *supra*; Nobriga, M.L., F. Feyrer, R.D. Baxter, and M. Chotkowski. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass. *Estuaries* 28(5):776-785; Jassby, A. 2008. “Phytoplankton in the Upper San Francisco Estuary: recent biomass trends, their causes, and their trophic significance.” *San Francisco Estuary and Watershed Science*. 6(1): Article 2, February 2008.

studying the Bay-Delta (Kimmerer 2005, Lehman 2000, Glibert 2010a,b, Winder and Jassby (in press), Slaughter and Kimmerer, 2010).²¹³

Thus, the species-specific acute and chronic effects of ammonia/um described in the Tentative Order are not the only impacts caused by the Treatment Plant. There is also a more complex shift in communities that occurs when nutrient loading increases and nutrient stoichiometry is altered (Cloern 2001; Sterner and Elser 2002).²¹⁴

The N:P ratio has long been shown to influence phytoplankton composition and the presence – or absence – of native species and vegetation, as extensive studies have repeatedly demonstrated in study after study across a range of systems in North Carolina, Hong Kong, Tunisia, Germany, Florida, Norway, Michigan, Spain, Korea, Japan, Washington DC (Chesapeake Bay), Tampa (Tampa Bay), and Denmark, to name just a few, as well as in the laboratory. Many of these findings are described in more detail below.

Studies have also suggested that the increased N:P ratio altered the native submerged aquatic vegetation in the Bay-Delta (Glibert 2010c).²¹⁵ The native vegetation has largely been replaced by invasive submerged and floating vegetation, including the Brazilian waterweed, *Egeria dense*, and the water hyacinth, *Eichhornia crassipes*. Although the water hyacinth was introduced some time ago (Finlayson 1983; Gopal 1987),²¹⁶ it has increased in abundance most significantly in recent decades (Finlayson 1983, Toft *et al.* 2003).²¹⁷ By the early 1980s, hyacinth covered approximately 500 ha, or about 22% of the waterways, in the Bay Delta (Finlayson 1983).²¹⁸ The exact timing of the invasion of the Brazilian waterweed is not well documented, but it too increased significantly during the decades of the 1980s (Jassby and Cloern 2000)²¹⁹ and 1990s (Anderson 1999),²²⁰ the period after phosphate removal and the increasing of the N:P ratio. The waterweed (*Egeria*), like *Hydrilla*, can reach high biomass levels and is well suited to thrive in a higher N:P environment (Reddy *et al.* 1987, Fiejoo *et al.* 2002).²²¹

Invasive vegetation and other species have likewise been observed in other ecosystems that experienced an increase in the N:P ratio, just as in the Bay-Delta (Glibert 2010c).²²² The Potomac River (Chesapeake Bay) was invaded by submerged aquatic vegetation, *Hydrilla* and clams, *Corbicula*, when the N:P ratio of effluent from the large Blue Plains sewage treatment facility increased after phosphorus was reduced in the 1980s (Ruhl and Rybicki 2010)²²³. In the Ebro River estuary in Spain, as well, both *Hydrilla* and

²¹³ Kimmerer, W. 2005. Long-term changes in apparent uptake of silica in the San Francisco Estuary. *Limnology and Oceanography*. 50(3):793-798; Lehman, 2000, *supra*; Glibert, 2010a, *supra*; Glibert, 2010b, *supra*; and Winder and Jassby, In press, *supra*; Slaughter and Kimmerer, 2010, *supra*.

²¹⁴ Cloern, J.E., 2001. Our evolving conceptual model of the coastal eutrophication problem. *Mar. Ecol. Prog. Ser.* 210:223-253; and Sterner and Elser, 2002, *supra*.

²¹⁵ Glibert, P. 2010c. Nutrients and the food web of the Bay Delta. Oral Presentation to the National Academy of Sciences Committee on Sustainable Water and Environmental Management in the California Bay-Delta, Sacramento, CA. July 13, 2010.

²¹⁶ Finlayson, B.J. 1983. Water hyacinth: Threat to the Delta? *Outdoor California* 44: 10-14; and Gopal, B. 1987. Aquatic plant studies. 1. Water hyacinth. Elsevier Publishing, New York.

²¹⁷ *Id.*; and Toft, J.D., C.A. Simestad, J.R. Cordekk and L.F. Grimaldo. 2003. The effects of introduced water hyacinth on habitat structure, invertebrate assemblages and fish diets. *Estuaries* 26: 746-758.

²¹⁸ Finlayson, 1983, *supra*.

²¹⁹ Jassby, A.D. and J.E. Cloern. 2000. Organic matter sources and rehabilitation of the Sacramento-San Joaquin Delta (California, USA). *Aquat. Conser: Mar. Freshw. Ecosyst.*, 10:323-352.

²²⁰ Anderson, L.W.J. 1999. *Egeria* invades the Sacramento-San Joaquin Delta. *Aquatic Nuisance Species Digest*. 3: 37-40

²²¹ Reddy, K.R., J.C. Tucker, and W.F. Debusk. 1987. The role of *Egeria* in removing nitrogen and phosphorus from nutrient enriched waters. *J. Aquat. Plant Management* 25: 14-19; and Feijoo, C., M.E. Garcia, F. Momo, and J. Tpjá. 2002. Nutrient absorption by the submerged macrophyte *Egeria dense* Planch: Effect of ammonium and phosphorus availability in the water column on growth and nutrient uptake. *Limnetica* 21: 93-104.

²²² Glibert, 2010c, *supra*.

²²³ Ruhl, H.A. and N.B. Rybicki. 2010. Long-term reductions in anthropogenic nutrients link to improvements in Chesapeake Bay habitat. www.pnas.org/cgi/doi/10.1073/pnas.1003590107.

Corbicula invaded shortly after phosphorus was removed from effluent (Ibanez *et al.* 2008).²²⁴

Other food web alterations occur in an altered N:P environment. For example, the expansion of species, such as *Microcystis*, which are well adapted to thrive at a wide range of N:P ratios, further disrupts ecosystems, including normal predator-prey interactions. There is a broad scientific literature on the relationship between N:P ratio and *Microcystis*. The scientific literature supports the conclusion that the recent increase in *Microcystis* blooms is likely attributed to shifts in the nutrient ratios and resulting changes in nutrient forms in the Delta. This emerging relationship is complex because the established paradigm is that cyanobacteria increase in lakes when they are enriched with nutrients (e.g. Paerl 1988, Downing *et al.* 2001).²²⁵ A study by Downing *et al.* (2001), involving data from 99 lakes around the world, showed that total P or N were important predictors of cyanobacteria. Some cyanobacteria, especially those with the capability for nitrogen fixation, do well under low N:P ratios (e.g., Smith 1983, Stahl-Delbanco *et al.* 2003).²²⁶ While there is a plasticity in the ability of cyanobacteria to grow in a wide range of environments, *Microcystis* is able to tolerate elevated N:P levels, and thus its dominance under high N:P may also reflect the decline in other species without such tolerances. Cyanobacteria do not have to grow faster at elevated N:P than at lower N:P values to become abundant, they merely have to grow faster than competing species groups (Glibert 2010a).²²⁷ Glibert (2010a) observed highly significant correlation between ammonium concentration and changes in cyanobacteria occurrence.²²⁸ Based on stable isotope analyses of particulate organic matter and nitrate, Kendall observed that ammonium, not nitrate, is the dominant source of nitrogen utilized by *Microcystis* at the Antioch and Mildred Island sites in the summer 2007 and 2008.²²⁹

Studies in Korea and Japan, and laboratory experiments have also related increasing N, and increasing N:P ratios, with increasing toxicity of *Microcystis*. In Daechung Reservoir, Korea, researchers found that toxicity was related not only to an increase in N in the water, but to the cellular N content as well (Oh, *et al.* 2001).²³⁰ A very recent report by van de Waal (2010) demonstrated in chemostat experiments that under high CO₂ and high N conditions, microcystin production was enhanced in *Microcystis*.²³¹ Similar relationships were reported for a field survey of the Hirosawa-no-ike fish pond in Kyoto, Japan, where the strongest correlations with microcystin were high concentrations of NO₃ and NH₄ and the seasonal peaks in *Microcystis* blooms were associated with extremely high N:P ratios (Ha *et al.* 2009).²³² Thus, not only is *Microcystis* abundance enhanced under high N:P, but its toxicity is as well (Oh *et al.* 2001).²³³ Support can also be found in studies of the Neuse River in North Carolina (Paerl 2009).²³⁴ There, as in the Bay-Delta, phosphorus was controlled when phosphates were removed from detergents, but there was

²²⁴ Ibanez, C., N. Prat, C. Duran, M. Pardos, A. Munne, R. Andreu, N. Caiola, N. Cid, H. Hampel, R. Sanchez, and R. Trobajo. 2008. Changes in dissolved nutrients in the lower Ebro river: Causes and consequences. *Limnetica*. 27(1):131-142.

²²⁵ Paerl, H.W. 1988. Nuisance phytoplankton blooms in coastal, estuarine, and inland waters. *Limnol. Oceanogr.* 33(4, part 2): 823-847; and Downing, J.A., S.B. Watson, and E. McCauley. 2001. Predicting cyanobacterial dominance in lakes. *Ca. J. Fish. Aquat. Sci.* 58: 1905-1908.

²²⁶ Smith, V.H. 1983. Low nitrogen to phosphorus ratios favor dominance by blue-green algae in lake phytoplankton. *Science* 221: 669-671; and Stahl-Delbanco, A., L.-A. Hansson and M. Gyllstrom. 2003. Recruitment of resting stages may induce blooms of *Microcystis* at low N:P ratios. *J. Plankt. Res.* 25: 1099-1106.

²²⁷ Glibert, 2010a, *supra*.

²²⁸ *Id.*

²²⁹ Kendall, C. 2010b. Use of stable isotopes for evaluating environmental conditions associated with *Microcystis* blooms in the Delta. Oral Presentation at the 6th Biennial Bay-Delta Science Conference, Sacramento, CA, September 27-29, 2010.

²³⁰ Oh, H-M., S.J. Lee, M-H. Jang and B-D. Yoon. 2000. Microcystin production by *Microcystis aeruginosa* in a phosphorus-limited chemostat. *Appl. Envir. Microbiol.* 66: 176-179.

²³¹ van de Waal, D.B. , L.Tonk, E. van Donk, H.C.P. Matthijs, P. M. Visser and J. Huisman. 2010. Climate Change And The Impact Of C:N Stoichiometry On Toxin Production By Harmful Cyanobacteria. Oral Presentaton at the 14th International HAB Conference, Greece.

²³² Ha, J.H., T. Hidaka, and H. Tsuno. 2009. Quantification of toxic *Microcystis* and evaluation of its dominance ratio in blooms using real-time PCR. *Envir. Sci. Technol.* 43: 812-818

²³³ Oh *et al.*, 2000, *supra*.

²³⁴ Paerl, H.W. 2009. Controlling Eutrophication along the Freshwater–Marine Continuum: Dual Nutrient (N and P) Reductions are Essential. *Estuaries and Coasts* 32:593–601

no contemporaneous reduction in nitrogen. The estuary ceased to function as an effective filter (e.g. Cloern 2001),²³⁵ resulting in the displacement of nitrogen loads downstream and enhancement of cyanobacterial dominance in the plankton (Paerl 2009).²³⁶

Cyanobacteria grow particularly well on ammonium while their competitors, such as the diatoms that are essential to the pelagic food web, do not.²³⁷ Cyanobacteria are able to adapt to high N:P ratios, while diatoms are generally not. In contrast, the literature establishes that diatoms may have a nutritional requirement for, and under some circumstances even a preference for, nitrate²³⁸ and diatoms are more often found to be abundant when nutrient ratios are at or near the 16:1 ratio. These relationships are well established from measurements of enzyme activities,²³⁹ directly determined rates of nitrogen uptake using isotope tracers,²⁴⁰ and growth studies, including Meyer *et al* (2009) who state that ammonia as nitrogen “produces the highest growth and primary production rates for *Microcystis aeruginosa* and other cyanobacteria...”²⁴¹

Scientific literature based on studies in Hong Kong, Tunisia, Germany, and Florida, likewise report on the consequences of shifting the N:P ratio to the low side of the “Redfield” ratio. These studies provide further support for the finding that diatoms are more often found to be abundant when nutrient ratios are at or near the 16:1 “Redfield” ratio and that other species, such as dinoflagellates have an advantage at lower N:P ratios. In the Bay-Delta, flagellates are most abundant at low N:P ratios (Glibert 2010b).²⁴² In Tolo Harbor, Hong Kong, nutrient loading, particularly phosphorus loading, increased due to population increases in the late 1980’s. The result was that a distinct shift from diatoms to dinoflagellates was observed in the harbor, coincident with a decrease in the N:P ratio from roughly 20:1 to <10:1 (Hodgkiss and Ho 1997; Hodgkiss 2001).²⁴³ Once the phosphorous was removed from the sewage effluent that was being discharged into the harbor and stoichiometric proportions were re-established, there was a resurgence of diatoms and a decrease in dinoflagellates.²⁴⁴ In Tunisian, aquaculture lagoons dinoflagellates have been shown to develop seasonally when N:P ratios decrease (Romdhane, *et al.* 1998).²⁴⁵ Comparable results have been observed in systems in Germany and along the coast of Florida.²⁴⁶

²³⁵ Cloern, J.E., 2001. *supra*.

²³⁶ Paerl 2009, *supra*.

²³⁷ Glibert, P.M., J. Boyer, C. Heil, C. Madden, B. Sturgis, and C. Wazniak. 2010. Blooms in Lagoons: Different from those of river-dominated estuaries. In: M. Kennish and H. Paerl, eds, *Coastal Lagoons: Critical habitats of environmental change*. Taylor and Francis.

²³⁸ See, e.g., Lomas and Glibert 1999a, *supra*. Lomas, M.W. and P.M. Glibert. 1999b. Temperature regulation of nitrate uptake: A novel hypothesis about nitrate uptake and reduction in cool-water diatoms. *Limnol Oceanogr* 44:556-572.

²³⁹ Solomon, C. Gallaudet Univ, unpub. data.

²⁴⁰ See, e.g., Glibert, P., C.A. Heil, D. Hollander, M. Revilla, A. Hoare, J. Alexander, S. Murasko. 2004. “Evidence for dissolved organic nitrogen and phosphorous uptake during a cyanobacterial bloom in Florida Bay.” *Mar. Ecol. Prog. Ser.* 280:73-83.

²⁴¹ See, e.g., Meyer, J.S., P.J. Mulholland, H.W. Paerl, and A.K. Ward. 2009. “A framework for research addressing the role of ammonia/ammonium in the Sacramento-San Joaquin Delta and the San Francisco Bay Estuary ecosystem.” Report to CalFed Science Program; and Berman, T and S. Chava, 1999. “Algal growth on organic compounds as nitrogen sources.” *Journal of Plankton Research* 21:1423-1437.

²⁴² Glibert, 2010b, *supra*.

²⁴³ Hodgkiss, I.J. and K.C. Ho. 1997. Are changes in N:P ratios in coastal waters the key to increased red tide blooms? *Hydrobiologia*. 352:141-147; Hodgkiss, I.J. 2001. The N:P ratio revisited. In: K.C. Ho and Z.D. Wang (Eds.), *Prevention and Management of Harmful Algal Blooms in the South China Sea*. School of Science and Technology, Open University of Hong Kong.

²⁴⁴ Lam, C. W. Y. and K. C. Ho. 1989. Red tides in Tolo Harbour, Hong Kong, p. 49–52. In T. Okaichi, D. M. Anderson, and T. Nemoto (eds.), *Red Tides: Biology, Environmental Science and Toxicology*. Elsevier, New York.

²⁴⁵ Romdhane, M.S., H.C. Eilertsen, O.K.D. Yahia, and Y.N.D. Daly. 1998. Toxic dinoflagellate blooms in Tunisian lagoons: causes and consequences for aquaculture. In: *Harmful Algae* Edited by B. Reguera, J. Blanco, M.L. Fernandez & T. Wyatt, Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, pp. 80–83.

²⁴⁶ See Water Agencies’ Comments on Aquatic Life at 18-19, *supra*.

Other components of the food web are also affected by changes in N:P ratios (Sterner and Elser 2002).²⁴⁷ Norwegian studies monitored lakes for many years and found that different zooplankton tend to dominate under different N:P ratios (Hessen 1997), due to the different phosphorus content of different species found in the lake.²⁴⁸ Hessen (1997), for example, showed that a shift from calanoid copepods to *Daphnia* tracked N:P; calanoid copepods retain proportionately more N, while *Daphnia* are proportionately more P rich. Studies from experimental whole lake ecosystems found that zooplankton size, composition and growth rates changed as the N:P ratio varied (e.g., Schindler 1974, Sterner and Elser 2002).²⁴⁹

Altered N:P ratios have also been shown to affect the relationships between piscivores and planktivores in freshwater systems (Sterner and Elser 2002), due to the differing demands for P-requiring bones and skeleton.²⁵⁰ These differences, in turn, have implications for the ability of different components of the food web to grow on foods that vary in N:P content.²⁵¹ Many fish species in the Bay Delta have demonstrated a similarly strong relationship with N:P over time (Glibert 2010a,c).²⁵²

f. Where implemented in impacted ecosystems, nutrient removal has improved the natural ecosystem and aquatic life.

As the numerous studies cited above demonstrate, it is both the N:P ratios and the form of N that drive the algal community composition which has important effects throughout the food web. Simply nitrifying the ammonia/um and discharging high nitrate loads in its place will not restore the N:P ratios. Total nitrogen loads need to be reduced. Requiring similar nutrient removal on wastewater treatment plants in other ecosystems, such as in the Chesapeake Bay, Tampa Bay, and coastal areas of Denmark, have proven to be effective at reversing the harmful effects of previously undertreated discharges and restoring the native systems.

For example, nutrient removal at the Blue Plains treatment plant in Washington, D.C. reduced the N:P ratios in the Potomac River and successfully reduced the invasive species, and native vegetation began to re-emerge in the river. Once a nitrification/denitrification system was installed at Blue Plains in the 1990s, with a goal of total N reductions to a maximum of 7.5 mg L⁻¹ and an ammonia nitrogen effluent limit (now as low as 4.2 mg L⁻¹), within several years, the abundance of the invasive *Hydrilla* began to decline and the abundance of native grasses increased (Ruhl and Rybicki 2010).²⁵³

Tampa Bay provides another important example. Eutrophication problems in the Bay were severe in the 1970s, with N loads approximating 24 tons per day, about half of which was due to point source effluent (less than the current Treatment Plant discharge of 14 tons per day) (Greening and Janicki 2006).²⁵⁴ Full nitrification and denitrification of the discharge was required at the regional treatment plant in the 1980s, and P was also reduced due to other best management practices. The native seagrass increased following nutrient removal, but it took several years.

The Tampa Bay study highlighted several key conclusions:

- It will take time to see improvements in an impacted ecosystem, because there are internal, existing loads of nutrients in sediment reservoirs from historic discharges. These historic loadings can therefore effectively prolong the system's responsiveness to external reductions of total N. This highlights the need to act expeditiously and reduce interim loads, as further discharges will only make restoring the native species of the

²⁴⁷ Sterner and Elser, 2002, *supra*.

²⁴⁸ Hessen, D.O.. 1997. Stoichiometry in food webs – Lotka revisited. *Oikos* 79: 195-200.

²⁴⁹ Schindler, D. W. 1974. Eutrophication and Recovery in Experimental Lakes: Implications for Lake Management. *Science*. 184(4139):897-899; and Sterner and Elser, 2002, *supra*.

²⁵⁰ Sterner and Elser, 2002, *supra*.

²⁵¹ Many fish species in the Bay Delta demonstrate a strong relationship with N:P over time (Glibert 2010a, *supra*).

²⁵² Glibert, 2010a, *supra*; and Glibert, 2010c, *supra*.

²⁵³ Ruhl and Rybicki, 2010, *supra*.

²⁵⁴ Greening, H. and A.Janicki. 2006. Toward reversal of eutrophic conditions in a subtropical estuary: Water quality and seagrass response to nitrogen loading reductions in Tampa Bay, Florida, USA. *Environ. Mgt.* 38(2):163-178.

River and Bay-Delta all the more difficult.

- Initial N reductions must be continually followed by reductions in future loadings if water quality gains are to be maintained.
- Continued and frequent monitoring of the system at environmentally relevant detection limits are required to allow managers to assess progress to water quality goals (Greening and Janicki 2006).²⁵⁵

Lower nutrient discharges also had positive effects on the coastal waters around the island of Funen, Denmark (Rask *et al.* 1999).²⁵⁶ Since the mid 1980s, there has been a roughly 50% reduction in the loading of N and P in the region due to point source reductions. Again, native grasses returned and low oxygen problems were reversed.

These examples of successful nutrient removal are not provided to predict with certainty that the ecosystem of the River and Bay-Delta will return to exactly what existed decades before the impacts began. Researchers (Duarte *et al.*, 2009)²⁵⁷ have surveyed the literature for systems that have undergone nutrient loading and nutrient reductions and the trajectories of response were complex and varied. They attributed this to “shifting baselines,” recognizing that systems have changed due to invasions, extinctions, overfishing, climate change and other factors. Yet, however difficult it may be to predict exactly how an individual system will respond, Duarte *et al.* (2009) concluded that “efforts to reduce nutrient inputs to eutrophied coastal ecosystems have indeed delivered important benefits by either leading to an improved status of coastal ecosystems or preventing damages and risks associated with further eutrophication.” (Duarte *et al.* 2009).²⁵⁸

g. The Treatment Plant discharge is depleting dissolved oxygen in the Sacramento River and the Bay-Delta.

As the Tentative Order provides, the Treatment Plant’s “effluent contains ammonia and BOD at levels that use all the assimilative capacity for oxygen demanding substances in the Sacramento-San Joaquin Delta. This results in no assimilative capacity for other cities and communities to discharge oxygen demanding constituents, which is needed for them to grow despite the fact that most of these cities and communities are already implementing Best Practical Treatment and Control (BPTC) at their own facilities and SRWTP is not.” Att. F. at F-55. The Tentative Order based this analysis on standard calculations relying on the modeling and data provided by the Sanitation District. Att. F at F-91. Based on those calculations, the Tentative Order documents extensive impacts many miles away from the outfall. *E.g.*, F-92 (“Ammonia, along with BOD, from the SRTWP reduces the dissolved oxygen (“DO”) in the Sacramento River and Sacramento-San Joaquin Delta for nearly 40 miles below its discharge”).

Additional data in the record before the Regional Board that were gathered by other state agencies confirm the Tentative Order’s conclusion that the current discharge is contributing to depressed DO levels downstream of the Treatment Plant. The Department of Water Resources (DWR) observed several periods in 2008 and again in 2009 when DO levels were below the Basin Plan’s established objective of 7 mg L⁻¹ at Hood.²⁵⁹ The Sanitation District claims that these measured data are erroneous,²⁶⁰ but DWR

²⁵⁵ *Ibid.*

²⁵⁶ Rask, N., S. E. Pedersen, and M. H. Jensen. 1999. Response to lowered nutrient discharges in the coastal waters around the island of Funen, Denmark. *Hydrobiologia* 393: 69–81.

²⁵⁷ Duarte, C.M., D.J. Conley, J. Carstensen, and M. Sánchez-Camacho. 2009. Return to Neverland: Shifting Baselines Affect Eutrophication Restoration Targets. *Estuaries and Coasts*. 32:29–36.

²⁵⁸ *Ibid.*

²⁵⁹ DWR monitoring data, 2008-2009, attached to, Department of Water Resources Office Memo from Sal Batmanghlich, Chief Real-time Monitoring Section to Kathleen Harder, Central Water Quality Control Board re Hood water quality station Dissolved Oxygen QA/QC data. July 22, 2010.

²⁶⁰ Larry Walker Associates. 2009. Low dissolved oxygen prevention assessment- Administrative Draft. Prepared for Sacramento Regional County Sanitation District.

reviewed their data and found no problems during the periods in question.²⁶¹

Moreover, that the daily discharge of thousands of pounds of untreated ammonia/um would deplete DO in the receiving waters is both standard chemistry and well established by observed data. Findings made by federal regulators in evaluating impacts to the salmon similarly concluded the increase in ammonia concentrations in the wastewater disposed of by the City of Stockton depressed DO levels causing impacts to aquatic life. In its Biological Opinion on salmon, NOAA's National Marine Fisheries Service found that "increased ammonia concentrations in the discharges from the City of Stockton Waste Water Treatment Facility lowers the [dissolved oxygen] in the adjacent [deep water ship channel] near the West Complex. In addition to the negative effects of the lowered DO on salmonid physiology, ammonia is in itself toxic to salmonids at low concentrations."²⁶² Davis *et al.* (1963) found that progressively lower DO concentrations below saturation had increasingly negative impact on juvenile salmonid swimming speed.²⁶² Impaired swimming ability impairs the ability of salmon to successfully feed, migrate, and avoid predation (Cramer, 2010).²⁶³

²⁶¹ Department of Water Resources Office Memo from Sal Batmanghilich, Chief Real-time Monitoring Section to Kathleen Harder, Central Valley Regional Water Quality Control Board re Hood water quality station Dissolved Oxygen QA/QC data. July 22, 2010.

²⁶² NOAA Fisheries. 2009. Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State Water Project. National Marine Fisheries Service, June 4, 2009 at page 157.

²⁶³ Cramer, Steve, Gaskill, Phil, and Vaughn, Jason. 2010. Impact of Sacramento Regional Wastewater Treatment Plant Effluent Discharges on Salmonids.

Attachment A



Bradley Cavallo,

Fishery Biologist, Senior Consultant

Education and Training

M.S. Aquatic Ecology,
University of Montana-
Missoula. 1997.

B.S. Wildlife and
Fisheries Biology,
University of California-
Davis. 1994.

Employment History

Senior Consultant,
Fisheries Scientist,
Cramer Fish Sciences.
Auburn, California.
2006–present.

*Senior Environmental
Scientist,* California
Department of Water
Resources.
Sacramento, California.
2003–2006.

*Environmental
Scientist,* California
Department of Water
Resources.
Sacramento, California.
1999–2003.

Brad is an experienced project and team leader, a diligent communicator, and a resourceful problem-solver with more than 10 years experience. He earned a Master of Science in Aquatic Ecology from University of Missoula (1997), a Bachelor of Science in Wildlife and Fisheries Biology from University of California at Davis (1994), and has since authored several dozen fishery reports, published papers and presentations. Brad possesses expert knowledge of regulated rivers, hydrogeology, fluvial geomorphology, floodplain-riparian ecology, suitable fish habitat, and critical evaluation of fish passage. He excels especially in high-level data analysis including simulation modeling, multivariate statistics, bootstrapping, generalized linear models and non-parametric statistics. Development, application and evaluation of quantitative models for assessing aquatic habitats and fish population dynamics are especially strong skills. Recent related projects include: 1) spring run Chinook life cycle model for evaluation of fish passage trap and haul program upstream of Oroville Facilities on the Feather River (CDWR), 2) temperature and discharge model effects assessment for alternative Oroville Facility operations and modification scenarios required by FERC re-licensing process (CDWR), 3) winter-run life cycle model development for use in evaluating alternative to Delta Cross Channel operations and long-term effects of the proposed North-of-Delta-Offstream-Storage project (Metropolitan Water District, CDWR), and 4) probabilistic simulation model for delta salmonid migration rules (State Water Contractors).

Brad has worked on numerous fisheries projects throughout the Central Valley including the Sacramento-San Joaquin Delta. Brad is expert in all sampling methodologies for fishes, water quality, invertebrates, the evaluation of habitat availability and quality among aquatic vertebrates; including development and application of techniques for assessing aquatic habitats and fish population dynamics. As a specific example, Brad acted as lead scientist for research programs assessing environmental impact of State Water Project operations on salmon and

Fisheries Biologist,
California Department
of Fish and Game.
Stockton, California.
1998–1999.

Scientific Aide,
California Department
of Fish and Game
Rancho. Cordova,
California. 1997–1999.

*Graduate Research
Assistant*, Flathead
Lake Biological
Station. Polson,
Montana. 1994–1997.

steelhead in the Feather River, Sacramento River and the Sacramento-San Joaquin Delta. In this project Brad was responsible for designing research elements, directing field work, analyzing data, and summarizing research findings in reports and presentations. Brad also has extensive training and experience with State and Federal environmental regulatory requirements including programs and policies relating to water quality and fish and wildlife resources.

Through his outstanding work Brad has established strong working relationships and positive rapport with resource agency staff. In September 2007, Brad was elected president and currently serves as president of the American Fisheries Society, California-Nevada Chapter.

Selected Publications and Reports

Cavallo, B., P. Bergman, C. Turner, and J. Merz. 2009. A simulation tool for integrating juvenile salmon migration and mortality data for improved understanding and management of the Sacramento-San Joaquin Delta. Submitted for peer review.

Hamilton, S., D. Murphy, J. Merz and B. Cavallo. 2009. A Quantitative, Multifactor Evaluation of Potential Causes of the Decline of the Delta Smelt. Submitted for peer review.

Cavallo, B., J. Merz, P. Bergman, and C. Turner. 2009. Review of delta smelt and longfin smelt monitoring program at Contra Costa and Pittsburg Power Plants. Cramer Fish Sciences Technical Report, available <http://www.fishsciences.net/reports/index.php>

Cavallo, B., R. Brown and D. Lee. 2009. Hatchery and Genetics Management Plan for Feather River Hatchery Spring-run Chinook Program. In review.

Gray, A., B. Cavallo, C. Watry, and J. Montgomery. 2009. Rotary Screw Trapping Operational Protocol: A Detailed Protocol for Rotary Screw Trapping Field Operations for the Stanislaus and Merced Rivers. Cramer Fish Sciences Technical Report, available <http://www.fishsciences.net/reports/index.php>

Cavallo, B. and R. Kurth. 2009. Steelhead (*Oncorhynchus Mykiss*) in a large, regulated tributary of the Sacramento River. In prep.

DWR. 2006. Draft Biological Assessment for Federally Listed Anadromous Fishes, Oroville Facilities Relicensing, FERC Project No. 2100. May 2006.

SP-F9 Final Report: The Effects of the Feather River Hatchery on

Naturally Spawning Salmonids. November 2004.

http://orovillereicensing.water.ca.gov/wg-reports_envir.html

SP-F10 Task 3A Final Report: Distribution and Habitat use of Juvenile Steelhead and Other Fishes of the Lower Feather River. April 2004. http://orovillereicensing.water.ca.gov/wg-reports_envir.html

SP-F10 Task 3B: Growth Investigations of Wild and Hatchery Steelhead in the Lower Feather River. April 2004. http://orovillereicensing.water.ca.gov/wg-reports_envir.html

SP-F16 Phase 2 Report: Evaluation of Project Effects on Instream Flows and Fish Habitat. April 2004. http://orovillereicensing.water.ca.gov/wg-reports_envir.html

Seesholtz, A., B. Cavallo and others. 2003. Lower Feather River juvenile fish communities: distribution, emigration patterns, and association with environmental variables. American Fisheries Society Symposium 39: 141-166.

DWR. 2002. Distribution of fishes in the lower Feather River in relation to season and temperature, 1997-2001. DWR, Division of Environmental Services Technical Report.

Cavallo, B.J. 1999. Modeling survival and testing hypothesis for adult striped bass using program MARK. California Department of Fish and Game Draft Technical Report.

Cavallo, B.J. and C.A. Frissell. 1997. Floodplain habitat heterogeneity and the distribution, abundance, and behavior of fishes and amphibians in the Middle Fork Flathead River basin, Montana. University of Montana, Masters Thesis.

Cavallo, B.J. and C.A. Frissell. 1996. Fishes, toads and natural floodplains: species distribution in diverse and thermally complex aquatic habitats. Intermountain Journal of Sciences 2: 27.

Cavallo, B.J. and M. Gard. 1994. Effects of flow regime on abundance of native fishes in lower Putah Creek. UC Davis, Department of Wildlife and Fisheries Biology File Report.

Professional Presentations

IEP Modeling Workshop, May 2009

“Fish Simulation Models for Evaluating Water Project Operations and Habitat Enhancements”

CALFED Science Conference, October 2008



“Central Valley Salmon Hatcheries: Fish factories or tools for ESA recovery?”

3rd Annual Spring-run Chinook Salmon Symposium, July 2008

“Managing hatchery salmon and regulated rivers to protect and restore spring run Chinook”

Interagency Ecological Program Annual meeting, February 2008

“The IOS Salmon Model: An Interactive “Blackboard” for Managers Evaluating Alternative Facilities, Operations and Enhancement Actions”

American Fisheries Society National Meeting, September 2007

“Segregation Weirs: Potential contribution to restoration of Central Valley spring run Chinook Salmon”

American Fisheries Society: Cal-Neva Chapter, March 2006

“Feather River Spring Run Chinook Salmon: Scourge or Salvation of the Central Valley ESU?”

CALFED Science Conference, October 2004

“Steelhead Abundance and Rearing Habits in a Regulated, Hatchery Influenced Central Valley River”

CALFED Adaptive Management Workshop, March 2002

“Experimental Flow Manipulations” (topic presenter and discussion leader)

DAVID K. FULLERTON

2804 Regina Way
Sacramento, CA 95818

EMPLOYMENT HISTORY

Principal Resource Specialist, Metropolitan Water District of Southern California 2001 – Present

- Recent work focused upon evaluation of various factors possibly linked to fishery declines: phytoplankton, zooplankton, ammonium, flow, salinity, turbidity, temperature, entrainment.
- Studies of smelt/turbidity relationships leading to current RMA smelt behavior model.
- Participation in BDCP, DRERIP technical committees.

Consultant, CALFED 1995 – 2001

- Architect, coordinator of Environmental Water Account

EDUCATION

Stanford University

MS	Electrical Engineering	1983
BS	Physics (With Distinction)	1980
BA	Classics	1980

University of California, Berkeley

MA	Ancient History: Specialty: Ancient Greece	1986
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AWARDS

H100 Leadership Award	California Water Policy 10 Conference	2000
Achievement Award	California Urban Water Conservation Council	1993
Conservation Achievement	CA Water Policy Conference	1992
Phi Beta Kappa	Stanford	1980
National Merit Scholar	Stanford	1975

SELECTED PUBLICATIONS

CALFED: Tinkering at the Edges, Environmental Science and Policy 12 (6), 733-736

Feasibility Study of a Maximal Program of Groundwater Banking. NHI. 12/98. (Coauthor)

An Environmentally Optimal Alternative for the Bay-Delta: A Response to the CALFED Program. NHI. 10/98. (Coauthor)

Breaking the Deadlock Over Water Management in the Central Valley. NHI. July 1995

Summary and Analysis: The Principles of Agreement on Bay-Delta Standards. Hastings West-Northwest Journal of Environmental Law and Policy. V 103. 1995

The California Model in Question. Courier De La Planete. No 24, 1994 (Coauthor)

California Water Policy: Adjusting to New Realities. California Water Law & Policy Reporter. Volume 3, Number 10. July 1993

Optimal Response to Periodic Shortage: Engineering/Economic Analysis for a Large Urban Water District. Anthony Fisher, David Fullerton, Nile Hatch, and Peter Reinelt. California Agricultural Experimental Station Giannini Foundation of Agricultural

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San Jose, CA 95118
(408) 265-2600

EDUCATION

B.A., Cum Laude, 1989, Colgate University, Hamilton, NY
Major in Biology and Minor in Environmental Studies
Beta, Beta, Beta, Biological Honor Society

PROFESSIONAL EXPERIENCE

- 8/05-present **Project Manager**, Santa Clara Valley Water District, San Jose, CA. Project manager in the Imported Water Program of the Water Utility Enterprise. Responsible for negotiating and managing research contracts; tracking fisheries and water quality research and informing managers and policy makers of results and implications; providing technical input on fisheries and water quality science to multiple Delta forums and processes. Develop Delta Project Plan and Stakeholder Engagement Plan.
- 2/01-8/05 **Senior Water Quality Specialist**, Santa Clara Valley Water District, San Jose, CA. Program manager for the Source Water Quality Management Program for the Water Utility Enterprise. Responsible for informing Water Utility and Water Supply Operations Divisions of trends and concerns with regard to water quality in all sources of supply; working with internal and external partners to develop and implement protection and improvement measures for all constituents of concern; and staying abreast of all new and proposed water quality regulations. Develop program strategic plan, priorities, and performance measures. Manage staff and consultant contracts, assist in unit budget process.
- 6/97-2/01 **Water Quality Specialist II**, Santa Clara Valley Water District, San Jose, CA. Program coordinator for the Nitrate Management Program within the Water Quality Unit. Project manager for the private well sampling program. Scheduled and conducted sampling and analysis of over 600 wells in six months. Developed a groundwater monitoring network to track the long term nitrate trends, including installation of new wells, execution of access agreements, and interpretation of results. Partnered with Monterey and Santa Cruz Counties on the production of agricultural outreach materials and workshops; reported to the public, media, and elected officials on the status of the program.
- 10/94-6/97 **Bioassay Laboratory Manager**, ToxScan, Inc., Watsonville, CA. Managed professional and technical staff and project scheduling, conducted performance evaluations, wrote Standard Operating Procedures and performed quality assurance and quality control checks of all data. Managed all aspects of two aquatic toxicology laboratories as well as performed all duties of staff toxicologist. Designed and performed non-point source Toxicity Identification Evaluations, dredge sediment Tier II and III bioassays and NPDES compliance monitoring testing. Researched and developed new bioassay procedures. Project manager for the Bioassay Laboratory Relocation Project. Designed the new facility, managed the construction contractors, tracked the project budget and schedule and directed project staff.

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- 8/93-10/94 **Assistant Bioassay Laboratory Manager**, ToxScan Inc., Watsonville, CA. Managed professional and technical staff scheduling, performed duties of Health and Safety Officer for Bioassay Division, oversaw personnel training program. Performed all aspects of aquatic bioassays including test design, water quality monitoring, set up, and end point determinations.
- 3/91-8/93 **Aquatic Toxicologist**, ToxScan Inc., Watsonville, CA. Performed all aspects of acute and short-term chronic bioassay protocols for effluent toxicity characterization using freshwater and marine species. Monitored water quality parameters throughout each bioassay.
- 6/90-12/90 **Environmental Programs Assistant**, City of Morgan Hill, Morgan Hill, CA. Implemented recycling, water conservation and other environmental programs and produced public education brochures and guides. Tracked public and private water use compared to pre-drought consumption levels. Established Environmental Hotline and coordinated summer camp program.
- 2/90-5/90 **Resource Assistant**, Lower Rio Grande Valley National Wildlife Refuge, Alamo, TX. Conducted plant and wildlife surveys, entered and analyzed data, assisted with greenhouse operations, assisted with refuge management and prepared tract management plan using Geographical Information System ARC/INFO.
- 9/89-2/90 **Research Intern**, Lloyd Center for Environmental Studies, S. Dartmouth, MA. Conducted water quality sampling and analysis, surveyed local residents, and wrote management report for the Town of Gosnold, MA. Provided administrative assistance for the Buzzards Bay Project and the Lloyd Center; staffed, and contributed articles to the Buzzards Bay Project Newsletter; wrote press releases.
- 9/87-6/89 **President**, Students for Environmental Awareness, Colgate University, Hamilton NY. Organized activities, facilitated meetings, managed budget and raised funds.
- 9/88-6/89 **Coordinator**, Colgate University Recycling Effort (CURE), Colgate University, Hamilton, NY. Established campus wide newspaper recycling program and initiated plans for a campus wide office paper recycling program.

PROFESSIONAL MEMBERSHIPS

Society for Environmental Toxicology and Chemistry
Coastal Estuarine Research Foundation

Lloyd W. Fryer

Consultant

Education

B.S. biological sciences, minors hydrology and economics.
University of California,
Bakersfield. 1980.

Employment History

Independent consultant, 2008-present.

Principal Water Resources Planner, Kern County Water Agency. 1992-2008 (retired).

Various other positions, Kern County Water Agency. 1980-1991.

Lloyd Fryer spent his entire career working for the Kern County Water Agency, the largest agricultural and third-largest urban contractor of the California Department of Water Resources. He has been involved with Bay-Delta science matters for the past 20+ years. During that time, he has been involved with nearly every regulatory effort involving State Water Project water supplies. He spent nearly 10 years in the information technology field and is expert in the use of database programs for storing and accessing biological, hydrological, and geological data.

He is currently involved in developing the State and Federal Contractors Water Agency's science program, which will expend up to \$2.5 million per year on research and studies relative to habitat restoration, water supply improvement, and non-water stressors on the Bay-Delta environment. The State and Federal Contractors Water Agency is a joint effort of State Water Project and Central Valley Project contractors.

Besides Bay-Delta science, Mr. Fryer is also very knowledgeable about agricultural water conservation and management. He was a founder of the Agricultural Water Management Council and was a member of its Board of Directors from its inception in 1996 until his retirement. He served on numerous committees related to agricultural water conservation and management, including the California Water Plan Advisory Committee, California Regional Water Quality Control Board stakeholder advisory workgroup for developing a long-term irrigated lands regulatory program, etc.

He authored the Kern County Water Agency's annual Water Supply Report, which provided a detailed accounting of the water supplies and demands within Kern County's main groundwater basin.

Selected Publications

Kern County Water Agency. 1980-2004. Water Supply Report. Published by Kern County Water Agency.

Kern County Water Agency. 1992. Crop Production and Water Supply Characteristics of Kern County. Published by Kern County Water Agency.

CURRICULUM VITAE

PATRICIA M. GLIBERT

Horn Point Laboratory

University of Maryland Center for Environmental Science

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Cambridge, MD 21613

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Email: glibert@hpl.umces.edu

I. Education

1974	BA	Skidmore College, Saratoga Springs, NY, Biology [<i>Phi Beta Kappa</i>]
1976	MS	University of New Hampshire, Earth Sciences
1982	PhD	Harvard University, Organismal and Evolutionary Biology

II. Professional Background

1981 - 1982	Postdoctoral Scholar, Woods Hole Oceanographic Institution
1982 - 1986	Assistant Scientist, Woods Hole Oceanographic Institution
1986 - 1989	Assistant Research Scientist, University of Maryland Center for Environmental Science, Horn Point Laboratory
1989 - 1993	Associate Professor, University of Maryland Center for Environmental Science, Horn Point Laboratory
1993 - present	Professor, University of Maryland Center for Environmental Science, Horn Point Laboratory

III. Recent Honors and Awards

2006. Recipient of the University of Maryland Board of Regents Award for Excellence in Research, Scholarship and Creative Activity

IV. Research

A. Research Interests

Transformations and fate of inorganic and organic nitrogen in marine and estuarine systems; global changes in the nitrogen cycle by anthropogenic activities; ecology of phytoplankton in coastal and oceanic environments; stable isotope techniques; eutrophication, its effects and global changes therein; growth and physiology of marine cyanobacteria and harmful algal bloom species; “top-down” control of nitrogen cycling; effects of harmful algae on early stages of shellfish growth; primary productivity and its regulation by environmental factors.

B. Peer-Reviewed Publications (2004-2009)

2004

Glibert, P.M., C.A. Heil, D. Hollander, M. Revilla, A. Hoare, J. Alexander, and S. Murasko. 2004. Evidence for dissolved organic nitrogen and phosphorus uptake during a cyanobacterial bloom in Florida Bay. *Mar. Ecol. Prog. Ser.* 280: 73-83.

- Dennison, W.C., T.J.B. Carruthers, J.E. Thomas, and P.M. **Glibert**. 2004. A comparison of issues and management approaches in Chesapeake Bay, USA, and Moreton Bay, Australia. In: W.H. Wong (ed), *Developments in ecosystems*, Vol. 1, Elsevier.
- Trice, T.M., P.M. **Glibert**, C. Lea, and L. Van Heukelem. 2004. HPLC pigment records provide evidence of past blooms of *Aureococcus anophagefferens* in the Coastal Bays of Maryland and Virginia, USA. *Harmful Algae*. 3: 295-304.
- Wazniak, C.E. and P.M. **Glibert**. 2004. Potential impacts of brown tide, *Aureococcus anophagefferens*, on juvenile hard clams, *Mercenaria mercenaria*, in the Coastal Bays of Maryland, USA. *Harmful Algae*. 3: 321-329.
- Glibert**, P.M. and R.E. Magnien. 2004. Harmful algal blooms in the Chesapeake Bay, USA: Common species, relationships to nutrient loading, management approaches, successes, and challenges, pp. 48-55. In: Hall, S., D. Anderson, J. Kleindinst, M. Zhu, and Y. Zou (eds.), *Harmful Algae Management and Mitigation*. Asia-Pacific Economic Cooperation (Singapore): APEC Publication #204-MR-04.2.
- Zhang, X., R.E. Hood, M.R. Roman, P.M. **Glibert**, and D. K. Stoecker. *Pfiesteria piscicida* population dynamics: A modeling study. 2004. In: K.A. Steidinger, J.H. Landsberg, C.R. Tomas, and G.A. Vargo (eds.), *Harmful Algae 2002, Proceedings of the Xth International Conference on Harmful Algae*. Florida Fish and Wildlife Conservation Commission and Intergovernmental Oceanographic Commission of UNESCO. Pp. 528-530.
- Glibert**, P.M., J. Alexander, T.M. Trice, B. Michael, R.E. Magnien, L. Lane, D. Oldach, and H. Bowers. Chronic urea nitrogen loading: A Correlate of *Pfiesteria* spp. in the Chesapeake and Coastal Bays of Maryland. 2004. In: K.A. Steidinger, J.H. Landsberg, C.R. Tomas, and G.A. Vargo (eds.), *Harmful Algae 2002, Proceedings of the Xth International Conference on Harmful Algae*. Florida Fish and Wildlife Conservation Commission and Intergovernmental Oceanographic Commission of UNESCO. pp. 74-76.
- 2005**
- Glibert**, P.M. and K.G. Sellner. 2005. Preface to the special issue on *Prorocentrum minimum*. *Harmful Algae* 4: 446.
- Heil, C.A., P. M. **Glibert** and C. Fan. 2005. *Prorocentrum minimum* (Pavillard) Schiller –A review of a harmful algal bloom species of growing worldwide importance. *Harmful Algae* 4: 449-470.
- Springer, J.J., J.M. Burkholder, H.B. Glasgow, P.M. **Glibert**, and R.E. Reed. 2005. Use of a real-time monitoring network (RTRM) and shipboard sampling to characterize a dinoflagellate bloom in the Neuse Estuary, North Carolina, U.S.A. *Harmful Algae* 4: 553-574.
- Fan, C., and P.M. **Glibert**. 2005. Effects of light on carbon and nitrogen uptake during a *Prorocentrum minimum* bloom. *Harmful Algae* 4: 629-642.
- Glibert**, P.M., T.M. Trice, B. Michael, and L. Lane. 2005. Urea in the tributaries of the Chesapeake and Coastal Bays of Maryland. *Water, Air and Soil Poll.* 160: 229-243.
- Glibert**, P.M. and G.C. Pitcher. 2005. Special issue on Harmful Algal Blooms. *Oceanography* 18(2): 134-135.
- Glibert**, P.M., D.M. Anderson, P. Gentien, E. Graneli, and K.G. Sellner. 2005 The global, complex phenomena of harmful algal blooms. *Oceanography* 18 (2): 136-147
- Glibert**, P.M. S. Seitzinger, C.A. Heil, J.M. Burkholder, M.W. Parrow, L.A. Codispoti, and V. Kelly. 2005. The role of eutrophication in the global proliferation of harmful algal blooms: new perspectives and new approaches. *Oceanography* 18(2): 198-209.
- Revilla, M., J. Alexander, and P.M. **Glibert**. 2005. Urea analysis in coastal waters: comparison of enzymatic and direct methods. *Limnol. Oceanogr. Methods* 3: 290-299.

Kemp, W.M., W.R. Boynton, J.E. Adolf, D.F. Boesch, W.C. Boicourt, G. Brush, J.C. Cornwell, T.R. Fisher¹, P.M. **Glibert**, J.D. Hagy, L.W. Harding, E.D. Houde, D.G. Kimmel, W.D. Miller, R.I.E. Newell, M. R. Roman¹, E.M. Smith, J.C. Stevenson. 2005. Eutrophication in Chesapeake Bay: Historical trends and ecological interactions. *Mar. Ecol. Prog. Ser.* 303: 1-29.

Glibert, P.M. and C. Heil. 2005. Use of urea fertilizers and the implications for increasing harmful algal blooms in the coastal zone. Science Press USA Inc., 541-544.

2006

Glibert, P.M. and C. Legrand. 2006. The diverse nutrient strategies of HABs: Focus on osmotrophy. pp 163-176 in: E. Graneli and J. Turner (eds.), *Ecology of Harmful Algae*. Springer.

Glibert, P.M. and J.M. Burkholder. 2006. The complex relationships between increasing fertilization of the earth, coastal eutrophication and proliferation of harmful algal blooms. pp 341-354 in: E. Graneli and J. Turner (eds.), *Ecology of Harmful Algae*. Springer.

Glibert, P.M. and J.M. Burkholder. 2006. The emerging consensus on the ecology of *Pfiesteria*: Preface to the special issue. *Harmful Algae*. 5: 339-341.

Glibert, P.M., J.M. Burkholder, M.W. Parrow, A.J. Lewitus, and D. Gustafson. 2006. Rates of direct uptake of nitrogen and nitrogen nutritional preferences by functional types of *Pfiesteria piscicida* and *Pfiesteria shumwayae*. *Harmful Algae*. 5: 380-394.

Hood, R., X. Zhang, P.M. **Glibert**, M.R. Roman and D. Stoecker. 2006. Modeling the influence of nutrients, turbulence and grazing on *Pfiesteria* dynamics. *Harmful Algae*. 5: 459-479.

Glibert, P.M., C.A. Heil, J.M. O'Neil, W.C. Dennison and M. J.H. O'Donohue. 2006. Nitrogen, phosphorus, silica and carbon in Moreton Bay, Queensland, Australia: Differential limitation of phytoplankton biomass and production. *Estuaries and Coasts* 29: 107-119.

Glibert, P.M., J. Harrison, C. Heil, and S. Seitzinger. 2006. Escalating worldwide use of urea – a global change contributing to coastal eutrophication. *Biogeochemistry* 77:441-463.

Wiegner, T.N., S.P. Seitzinger, P.M. **Glibert** and D.A. Bronk. 2006. Bioavailability of dissolved organic nitrogen and carbon from nine rivers in the eastern United States. *Aq. Microb. Ecol.* 43: 277-287.

Burkholder, J.M. and P. M. **Glibert**. 2006. Intraspecific variability: An important consideration in forming generalizations about toxigenic algal species. *S. Africa J. Mar. Sci.* 28: 177-180.

2007

Heil, C.A., M. Revilla, **P.M. Glibert** and S. Murasko. 2007. Nutrient quality drives phytoplankton community composition on the West Florida Shelf. *Limnol. Oceanogr.* 52: 1067-1078.

Kennish, M., S.B. Bricker, W.C. Dennison, **P.M. Glibert**, R.J. Livingston, K.A. Moore, R.T. Noble, H.W. Paerl, J. Ramstack, S. Seitzinger, D.A. Tomasko, and I. Valiela. 2007. Barnegat Bay-Little Egg Harbor Estuary: Case study of a highly eutrophic coastal bay system. *Ecol. Applications*. 17(5):S3-S16.

Glibert, P.M., C.E. Wazniak, M. Hall and B. Sturgis. 2007. Seasonal and interannual trends in nitrogen in Maryland's Coastal Bays and relationships with brown tide. *Ecol. Applications* 17 (5): S79-S87.

Solomon, C.M., J.A. Alexander and **P.M. Glibert**. 2007. Measuring urease in environmental samples. *Limnol. Oceanogr. Methods*. 5:280-288.

Glibert, P.M., J. Alexander, D.W. Meritt, E.W. North and D.K. Stoecker. 2007. Harmful algae pose additional challenges for oyster restoration: Impacts of the harmful algae *Karlodinium veneficum* and *Prorocentrum minimum* on early life stages of the oysters *Crassostrea virginica* and *Crassostrea ariakensis*. *J. Shellfish Res.* 26: 919-925.

2008

Stoecker, D.K., J.E. Adolf, A.R. Place, **P.M. Glibert**, and D. Meritt. 2008. Effects of the dinoflagellates *Karlodinium veneficum* and *Prorocentrum minimum* on early life history stages of the Eastern Oyster, *Crassostrea virginica*. *Marine Biology* 154: 81-90.

Alexander, J.A. D. K. Stoecker, D. W. Meritt, S. T. Alexander, A. Padeletti, D. Johns, L. Van Heukelem and **P. M. Glibert**. 2008. Differential feces and pseudofeces production by the oyster *Crassostrea ariakensis* when exposed to diets containing harmful dinoflagellate and raphidophyte species. *J. Shellfish Res.* 27: 567-579.

Glibert, P.M., R. Azanza, M. Burford, K. Furuya, E. Abal, A. Al-Azri, F. Al-Yamani, P. Andersen, D.M. Anderson, J. Beardall, G. M. Berg, L. Brand, D. Bronk, J. Brookes, J. M. Burkholder, A. Cembella, W. P. Cochlan, J. Collier, Y. Collos, R. Diaz, M. Doblin, T. Drennen, S. Dyhrman, Y. Fukuyo, M. Furnas, J. Galloway, E. Granéli, D. V. Ha, G. Hallegraeff, J. Harrison, P. J. Harrison, C. A. Heil, K. Heimann, R. Howarth, C. Jauzein, A. A. Kana, T. M. Kana, H. Kim, R. Kudela, C. Legrand, M. Mallin, M. Mulholland, S. Murray, J. O'Neil, G. Pitcher, Y. Qi, N. Rabalais R. Raine, S. Seitzinger, P. Salomon, C. Solomon, D.K. Stoecker, G. Usup, J. Wilson, K. Yin, M. Zhou, M. Zhu. 2008. Ocean urea fertilization for carbon credits poses high ecological risks. *Marine Pollution Bulletin* 56: 1049-1056.

Glibert, P.M. 2008. Ocean urea fertilization: A high risk plan and a unified international response. *Coastal and Estuarine Research Federation Newsletter* 34 (2): 4-5.

Solomon, C.M., and **P.M. Glibert**. 2008. Urease activity in five phytoplankton species. *Aq. Microb. Ecol.* 52: 149-157.

Glibert, P.M., J.M. Burkholder, E. Graneli and D.M. Anderson. 2008. Advances and insights in the complex relationships between eutrophication and HABs : Preface to the special issue. *Harmful Algae* 8: 1-2.

Heisler, J., **P. M. Glibert**, J. Burkholder, D. Anderson, W. Cochlan, W. Dennison, Q. Dortch, C. Gobler, C. Heil, E. Humphries, A. Lewitus, R. Magnien, H. Marshall, K. Sellner, D. Stockwell, D. Stoecker, and M. Suddleson. 2008. Eutrophication and harmful algal blooms: A scientific consensus. *Harmful Algae*. 8: 3-13.

Glibert, P.M., E. Mayorga and S. Seitzinger. 2008. *Prorocentrum minimum* tracks anthropogenic nitrogen and phosphorus inputs on a global basis: application of spatially explicit nutrient export models. *Harmful Algae*. 8: 33-38.

Anderson, D.A., J.M. Burkholder, W. Cochlan, **P. M. Glibert**, C. Gobler, Heil, R. Kudela, T. Parsons, V. Trainer and G. Vargo. 2008. Harmful algal blooms in the United States: Linkages to eutrophication. *Harmful Algae*. 8: 39-53.

Burkholder, J.M., **P.M. Glibert**, H. Skelton. 2008. Mixotrophy, a major mode of nutrition for harmful algal species in eutrophic waters. *Harmful Algae*. 8: 77-93.

Glibert, P.M., V. Kelly, L.A. Codispoti, W.C. Boicourt, T.M. Trice and B. Michael. 2008. *In situ* nutrient monitoring: A tool for capturing nutrient variability and the antecedent conditions that support algal blooms. *Harmful Algae*. 8: 175-181.

Glibert, P.M. 2008. Why the global change in nitrogen should concern us. *Public Affairs Journal*. November 2008: 44-51.

Li, J., **P.M. Glibert**, S. Lu, X. Shi and C. Zhang. 2008. Nitrogen uptake rates during a *Karenia mikimotoi* bloom in the East China Sea, 2005, and variation with N:P ratio. In: O. Moestrop, ed., Proceedings XII International Conference on Harmful Algae. IOC of UNESCO, Copenhagen, pp. 40-44.

2009

Glibert, P.M. and G.M. Berg. 2009. Nitrogen form, fate and phytoplankton composition. In: Kennedy, V.S., W.M. Kemp, J.E. Peterson and W.C. Dennison (eds), *Experimental Ecosystems and Scale: Tools for understanding and managing coastal ecosystems*. Springer.

Glibert, P.M., J.M. Burkholder, T.M. Kana, J.A. Alexander, C. Schiller, and H. Skelton. Grazing by *Karenia brevis* on *Synechococcus* enhances their growth rate and may help to sustain blooms. *Aquat. Microb. Ecol.* 55: 17-30.

Wazniak, C.A., M.R. Hall, E.A. Bailey, D.M. Boward, W.R. Boynton, J.F. Bratton, T.J.B. Carruthers, R.J. Chalmers, L.W. Cole, J.C. Cornwell, **P.M. Glibert**, A.B. Jones, T.E. Jordan, J. McCoy, M. McGinty, R.J. Shedlock, J. Sherwell, R.B. Sturgis, J.E. Thomas, T.M. Trice, and D.V. Wells. 2009. Water quality responses to nutrients. In: W.C. Dennison, J.E. Thomas, C.J. Cain, T.J.B. Carruthers, M.R. Hall, R.V. Jesien, C.A. Wazniak, and D.E. Wilson [eds.], *Shifting Sands: Environmental and cultural change in Maryland's Coastal Bays*.

In Press

Sinclair, G., D. Kamykowski and **P.M. Glibert**. 2009. Growth, uptake and assimilation of ammonium, nitrate and urea by three strains of *Karenia brevis* under low light conditions. *Harmful Algae*.

Johnson, P., A. Townsend, C.C. Cleveland, **P.M. Glibert**, R. Howarth, V. Mackenzie E. Rejmankova and M. Ward. Linking environmental nutrient enrichment and disease emergence in humans and wildlife. *Ecol. Applications*.

Glibert, P.M. and J. Oliver. A framework for estuarine nutrient criteria development in the US. *Tearmann: the Irish Journal of Agri-environmental Research*.

Glibert, P.M. Eutrophication and Harmful Algal Blooms: A Complex Global Issue, Examples from the Arabian Seas including Kuwait Bay, and an Introduction to the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) Programme. *International Journal of Oceans and Oceanography*.

Glibert, P.M., P.W. Boyd, and J.J. Cullen. Commercial ocean fertilization: Implications for harmful algal blooms. 13th International HAB Symposium proceedings.

Li, J., **P. M. Glibert**, M. Zhou, S. Lu, and D Lu. 2009. Relationships between nitrogen and phosphorus forms and ratios and the development of dinoflagellate blooms in the East China Sea. *Mar. Ecol. Prog. Ser.*

Glibert, P.M., J. Boyer, C. Heil, C. Madden, B. Sturgis, and C. Wazniak. Blooms in Lagoons: Different from those of river-dominated estuaries. In: M. Kennish and H. Paerl (eds.), *Coastal Lagoons: Critical habitats of environmental change*. Taylor and Francis.

Glibert, P.M., C.A. Heil, D. Rudnick, C.J. Madden, J. Boyer, and S. Kelly. Florida Bay: Status, trends, new blooms, recurrent problems. *Contrib. Mar. Sci.*

C. Peer-Reviewed Reports since 2004

2005

HARRNESS 2005. Ramsdell, J.S., D.M. Anderson, and **P.M. Glibert**, eds. Harmful Algal Research and Response: A National Environmental Science Strategy 2005-2015. Ecological Society of America, Washington D.C., 100 pg.

2006

GEOHAB 2006. Global Ecology and Oceanography of Harmful Algal Blooms: Eutrophication and HABs. P. Glibert, ed. IOC and SCOR, Paris and Baltimore.

2008

Dortch, Q. D. Anderson, D. Ayers and P. Glibert. 2008. Harmful Algal Bloom Research, Development, Demonstration and Technology Transfer. NOAA.

In press

Glibert, P.M., C. Madden, W. Boynton, D. Flemer, C. Heil and J. Sharp (eds.), *Estuarine Nutrient Criteria Development: State of the Science*. EPA Office of Water, in press.

D. Seminars and Presentations (2004-2008)

Glibert, P. 2004. Urea got a hold on me! Woods Hole Oceanographic Institution, Feb 2004

Glibert, P. Urea got a hold on me! Horn Point Laboratory, March 2004

Glibert, P. 2004. Nutrient inputs and phytoplankton blooms: It's quality not just quantity that counts. Impacts to coastal systems Symposium 2004, Rutgers University, March 2004

Glibert, P.M. 2004. The global increase in use of urea fertilizers and the implications for increasing harmful blooms in the coastal zone. N2004, Nanjing China.

Glibert, P.M. 2004. Eutrophication and HABs – Impacts of Global Changes in Fertilizer Use. XI Conference on HABs, Cape Town, S. Africa. **Invited Plenary.**

Glibert, P.M. J.J. Evans, P.H. Klesius, C.A. Shoemaker, and J.A. Alexander. 2005. Comparison of two fish kill events involving human bacterial pathogens: Influence of environmental stressors and harmful algae AGU-ASLO, Salt Lake City.

Glibert, P.M. C. A. Heil, J. Alexander, M. Revilla, and S. Murasko. 2005. Urea is a good predictor of cyanobacteria in Florida Bay and on the western Florida Shelf. 3rd Symposium on HABs in the U.S., Monterey CA, October 2005.

Glibert, P.M., J. Ramsdell and D. Anderson. 2005. Harmful Algal research and Response: An environmental science strategy. 3rd Symposium on HABs in the U.S., Monterey CA, October 2005. **Invited.**

Glibert, P.M. HABs and eutrophication- a synthesis. ERF Meeting, Norfolk, VA, October 2005. **Invited.**

Glibert, P.M. 2005. Brown tides and Eutrophication. Brown tide symposium for managers, Yapank, NY, November 2005. **Invited**

Glibert, P.M. 2005. National and international programs on HABs. Brown tide symposium for managers, Yapank, NY, November 2005. **Invited**

Glibert, P.M. C. A. Heil, J. Alexander, M. Revilla, S. Murasko, A. Hoare, J. O'Neil, W.C. Dennison and D. Hollander. 2005. Organic and Inorganic Nutrients, Rates of Phytoplankton Nutrient Uptake, and Their Relationship with Phytoplankton Community Composition in Florida Bay and in a Comparative Subtropical Ecosystem in Australia. Florida Bay Science Conference, Duck Key, FL, December 2005.

Glibert, P.M. Maryland's Coastal Bays. EPA Expert Workgroup on Nutrients in Estuaries Meeting, San Francisco, May 2006.

- Glibert, P.M., C.A. Heil, J. Alexander, M. Revilla, and S. Murasko. 2006. Urea uptake is positively correlated with the fraction of cyanobacteria in Florida coastal waters. ASLO, Victoria, Canada, June 2006.
- Glibert, P.M. Maryland's Coastal Bays. Coastal Bay's STAC Meeting, July 2006.
- Glibert, P.M., S. Seitzinger, R.W. Howarth, J. Burkholder. 2006. Eutrophication and HABs- A Global Change Perspective. 12th International HAB Symposium. Copenhagen, Sept. 2006.
- Glibert, P.M. 2006. HABs and Eutrophication. Cornell University, **Invited seminar**, Nov. 2006.
- Glibert, P.M. 2007. HABs and Eutrophication. University of Helsinki. **Invited seminar**. January 2007.
- Glibert, P.M. 2007. Effect of several common HAB species from Chesapeake Bay on early life history stages of *Crassostrea virginica* and *C. ariakensis*. February 2007. Web-seminar from Horn Point Laboratory.
- Glibert, P.M. 2007. HABs and Eutrophication and Introduction to the GEOHAB Programme. The Arabian Seas International Conference on Science and Technology of Aquaculture, Fisheries and Oceanography. Kuwait, February 2007. **Invited Plenary**.
- Glibert, P.M., 2007. A review of the 2001 Kuwait Fish Kill. The Arabian Seas International Conference on Science and Technology of Aquaculture, Fisheries and Oceanography. Kuwait, February 2007.
- Glibert, P.M. 2007. Harmful Algal Blooms- Increasing prevalence of microbial toxins and impacts. American Museum of Natural History, Special Symposium on Microbes, New York City, April 2007. **Invited Plenary**.
- Glibert, P.M. 2007. Harmful Algal Blooms- Increasing prevalence of microbial toxins and impacts. International Whaling Commission Science Symposium. Alaska, May 2007. **Invited**.
- Glibert, P.M. 2007. HARNNESS: The US National Plan for Harmful Algae. Workshop on Research, Development, Demonstration and Technology Transfer, Woods Hole, June 2007. **Invited**.
- Glibert, P.M. 2007. HABs and Eutrophication. Hong Kong University of Science and Technology. June 2007. **Invited**.
- Glibert, P.M. 2007. Aquatic eutrophication and Harmful Algal Bloom global expansion. Fourth International Conference on Nitrogen, Brazil, October 2007.
- Glibert, P.M., J. Alexander, D. Stoecker, E. North, and D. Meritt. 2007. Impacts of eutrophication-related blooms of *Prorocentrum minimum* and *Karlodinium veneficum* on early life stages of oysters in Chesapeake Bay. 4th Symposium on Harmful Algae, Woods Hole, October 2007.
- Glibert, P.M., C. Heil, J. Alexander, S. Murasko, M. Revilla and M.B. Neely. 2007. Role of dissolved organic material in supporting microalgal communities in Florida Bay. ERF 2007. Providence, RI, November 2007.
- Glibert, P.M. and C. Heil. 2008. Role of dissolved organic material in supporting microalgal communities in Florida Bay. Special DOM Workshop on Florida Bay. South Florida Water Management District, Miami, January 2008. **Invited**.
- Glibert, P.M. and J. Li. 2008. Nitrogen uptake rates during the HAB events of 2005 in the East China Sea and comparisons with recent dinoflagellate blooms in the western Florida Shelf. 2nd Asian GEOHAB Meeting, Nha Trang, Vietnam, January 2008.
- Glibert, P.M. 2008. Overview of the GEOHAB core research project on HABs in Eutrophic Systems. 2nd Asian GEOHAB Meeting, Nha Trang, Vietnam, January 2008.
- Glibert, P.M. 2008. Eutrophication and HABs: Focus on the Mid Atlantic. Ocean Sciences Meeting, Orlando, Florida. February 2008.

- Glibert, P.M. 2008. Chesapeake and Coastal Bay HABs and nutrients: Global models and ecosystem comparisons. Harmful Algal Bloom Task Force Meeting, Annapolis, April 2008.
- Glibert, P.M. 2008. A review of HABs of the Mid-Atlantic. DE Sea Grant-sponsored symposium of HABs. Lewis, DE. April 2008. **Invited keynote.**
- Glibert, P.M. 2008. *Prorocentrum minimum* tracks global nitrogen export. SCOR/LOICZ Working Group 132 Annual Meeting. Geeschacht, Germany, July 2008.
- Glibert, P.M., 2008. Complexity in the relationship between eutrophication and HABs. New College, FL, September 2008. **Invited seminar.**
- Glibert, P.M. 2008. Global nutrient over-enrichment: What's the relevance for the Florida coast? New College, FL, September 2008. **Invited seminar.**
- Glibert, P.M. 2008. Commercial ocean fertilization: Implication for harmful algal blooms. 13th International HAB Meeting, Hong Kong, November 2008.
- Glibert, P.M. 2008. A framework for estuarine nutrient criteria development in the U.S. Teagasc grassland and EU Water Framework Conference 2008. Wexford, Ireland, November 2008. **Invited keynote.**
- Glibert, P.M. C.A. Heil, S. Murasko, J. Alexander, MB Neely, and C. Madden. 2008. Dissolved organic material and the adaptive physiology of *Synechococcus* help to sustain blooms in Florida Bay. Florida Bay and Adjacent Marine Systems Science conference, Naples FL, December 2008.
- Glibert, P.M., J. Boyer, C.A. Heil, C. Madden, B. Sturgis and C. Wazni. 2009. Blooms in lagoons. Atlantic Estuarine Research Society, Ocean City, MD, March 2009. **Invited.**
- Glibert, P.M. 2009. HABs in estuaries and coastal lagoons. Ecosystem Based Management; The Chesapeake and Other Systems conference, Baltimore MD, March 2009, **Invited.**

E. Meetings and symposia organized since 2004

- Convener, GEOHAB Open Science Meeting on HABs and Eutrophication, Baltimore, March 2005. 130 attendees.
- Special session chair, HABs and eutrophication. ASLO 2005, Santiago
- Steering committee member, Third Symposium on Harmful Marine Algae in the U.S., Monterey, CA. 180 attendees.
- Special session chair. Harmful algal blooms. ERF 2005, Norfolk, VA.
- Co-convener, ASLO 2006, Victoria Canada. ~1500 attendees.
- Steering Committee member, NOAA workshop on Research, Development and Technology Transfer of Harmful Algal Blooms, Woods Hole, July 2007, 45 attendees.
- Steering Committee member, GEOHAB Modeling Workshop, June 2009. 60 attendees expected.
- Co-convener, 2nd Open Science Meeting on HABs and Eutrophication. Beijing, October 2009. ~200 attendees expected.
- Session Co-Chair, CERF 2009, Portland, Oregon, Estuarine Nutrient Criteria.
- Session Co-chair, CERF 2009, Portland, Oregon, Long-term Perturbations in Nutrients and Productivity
- Steering Committee member, 14th International HAB Conference, Greece, 2011.

F. Membership in Professional Societies

American Society for Limnology and Oceanography
 American Geophysical Union
 The Oceanography Society
 Estuarine Research Federation
 International Society for the Study of Harmful Algae

V. Outreach and Service

A. Editorships

Subject Editor, *Aquatic Microbial Ecology*, 1995-2001, 2007-present
Member of Editorial board of *Estuaries and Coasts*, 2004- present
Member of Editorial Board, *Harmful Algae*, 2001-present
Member of the Reader Review Panel, *Nature*, 2008-present

Guest Editor, special issue of *Harmful Algae* on *Prorocentrum minimum*, 2005
Guest Editor, special ½ issue of *Oceanography* on *HABs*, 2005
Guest Editor, special issue of *Harmful Algae* on the *Ecology of Pfiesteria*, 2006
Guest Editor, special issue of *Harmful Algae* on *HABs and Eutrophication*, 2008
Guest Editor, special issue of *Harmful Algae* on *Strain Differences in Harmful Algae*, 2009
Guest Editor, special issue of *Contributions in Marine Science* on *Florida Bay*, in prep.

B. Federal, State, Local Government

Member, Harmful Algal Technical Advisory Committee, 1999- present
Panelist, NIH Oceans and Human Health proposal evaluation, 2004
Panelist, NSF Biocomplexity panel, 2005
Member and lead report editor, EPA Working Group on nutrient criteria for estuaries, 2005-2008
Co-Chair, US National HAB Committee

C. International

GEOHAB Scientific Steering Committee and Focus Leader on Eutrophication, 1999-present
Co-chair, SCOR/LOICZ Working Group 132, Land based nutrient pollution and HABs, 2008-2011,
Steering Committee Member, UNESCO Global Nutrient Export from Watersheds- User Scenario Evaluation Working Group, 2009-present
Consultant to Kuwait Environment Public Authority on harmful algal blooms, 1999-2003

D. Other Professional Service

Member, Board of Trustees, Gunston Day School, 1999-2008; 2009- present
Panelist, International Fellowship Awards, American Association of University Women, 2006
Panelist and reviewer, Heinz Center evaluation of ecological effects of air quality, 2008-2009.
Expert Reviewer, Florida nutrient criteria development, 2009.

TERRY ERLEWINE

State Water Contractors
1121 L Street, Suite 1015, Sacramento, California 95814

EDUCATION

M.S., Civil Engineering, University of California, Davis, 1988)

B.S., Civil Engineering, University of California, Davis, 1977

CERTIFICATION

Registered Civil Engineer, State of California

EXPERIENCE

Mr. Erlewine is the General Manager of the State Water Contractors and has devoted his entire career to California water supply management and planning. State Water Contractors (SWC) is a non-profit mutual benefit corporation that represents that interests of the 27 public agencies located throughout California that receive water from the California State Water Project (SWP). As General Manager of SWC, Mr. Erlewine is directly responsible for overseeing and carrying out the objectives of SWC, including, but not limited to: timely completion of SWP facilities; assisting to ensure proper and efficient SWP operations; protection of water rights needed by the SWP and the SWC Member Agencies; review and coordination of litigation affecting the SWP; presentation of SWC views to legislative and administrative agencies, myriad stakeholders, interested parties, and the general public; and development and maintenance of a public information program about the SWP. In addition to these and other responsibilities, Mr. Erlewine plays a key role in coordinating with the California Department of Water Resources with regard to statewide SWP operations, water supply management and deliveries, and the numerous institutional efforts, programs, policies, environmental regulations, and multi-party agreements affecting SWP operations. Mr. Erlewine is also responsible for developing, managing and disseminating information as it pertains to SWP delivery facilities, including current water supply and water quality conditions, flow and storage data, flood and drought status, and all regulatory matters affecting the SWP. In addition, Mr. Erlewine oversees the SWC's participation in the current and developing framework for managing water supply and ecological issues within the Sacramento-San Joaquin Bay-Delta.

STATE WATER CONTRACTORS (1994 to Present)

- General Manager
- Assistant General Manager
- Principal Engineer

BOOKMAN-EDMONSTON ENGINEERING (1991 to 1994)

- Supervising Engineer

CALIFORNIA DEPARTMENT OF WATER RESOURCES (1978 to 1991)

- Senior Engineer, Water Resources
- Staff Engineer, Water Resources

ASSOCIATIONS

American Society of Civil Engineers (1978 to 1998)

American Geophysical Union (1984 to 1993)

American Water Works Association (1996 to 2002)

Michael E. Aceituno, Senior Consultant/Fishery Biology

Discipline/Specialty

- Fishery Biology
- Aquatic Ecology
- Marine Biology
- Biological Assessments
- Instream Flow Assessments
- Habitat Assessments & Suitability Analyses
- Resource Management Planning
- Project Management
- Endangered Species Act
- Section 7 Consultations
- Section 10 HCP's
- Magnuson-Stevens Fishery Conservation and Management Act
- Essential Fish Habitat (EFH) Assessments

Education

- M.S., Biological Sciences (Conservation), California State University, Sacramento, 1974
- B.S., Biological Sciences California State University, Sacramento 1971

Professional Affiliations

- American Fisheries Society

SUMMARY OF QUALIFICATIONS

Mr. Aceituno has over 34 years experience in marine and freshwater fishery management, aquatic habitat restoration, water development project evaluations, biological and ecological assessments, endangered species act (ESA) consultations, habitat conservation planning, Magnuson-Stevens Fishery Conservation and Management Act (MSA) Essential Fish Habitat (EFH) consultations and general regulatory compliance in California.

His technical experience includes managing and completing complex ESA Section 7 consultations and Section 10 Habitat Conservation Plans along with a variety of general aquatic and instream flow assessments, biological evaluations, effects analyses, and fisheries studies resulting in numerous technical reports. These reports led to the development of conservation measures, habitat restoration actions, and long-term plans, providing a combination of stream flows and physical habitat improvements, on such rivers as the Trinity, Stanislaus, Tuolumne, American, and Feather Rivers, all important components of California's water supply system.

He has provided expert witness testimony and declarations relative to California water use, water quality and fishery resources. He has conducted marine and freshwater fisheries analyses, watershed assessments and performed environmental restoration planning and monitoring throughout California. His projects have included preparation of NEPA documentation, completed ESA biological assessments, biological opinions and Habitat Conservation Planning, and Magnuson-Stevens Act (MSA), Essential Fish Habitat (EFH) consultations for Pacific salmon, groundfish, and coastal pelagic species. The results of these analyses included the quantification of available and/or potential fish habitat and the development of reasonable alternatives or conservation measures to protect fish while allowing for development to move forward.

Mr. Aceituno is a recognized expert in his field and has served on multiple advisory teams associated with marine resources, anadromous fisheries, species conservation, endangered species recovery, and the conservation of essential fish habitat. These include the Trinity River Task Force, the California Bay-Delta Authority, and the Bay Delta Conservation Plan (BDCP) Steering Committee. He is a skilled negotiator, mediator, and has managed numerous large-scale projects. Mr. Aceituno's expertise has focused on utilizing sound scientific techniques to obtain information necessary to resolve conflicts associated with marine and

Michael E. Aceituno, Senior Consultant/Fishery Biology

freshwater species conservation and competing resource uses. Over the years, he has developed and maintained close working relationships with policy makers, resource agency personnel, researchers, resource developers, environmental groups, stakeholders, and elected officials. As a result, he has successfully developed collaborative approaches to resolving resource management issues and conflicts.

RELEVANT EXPERIENCE

Endangered Species Act (ESA)/Magnuson-Stevens Fishery Conservation & Management Act (MSA) Projects

Program Manager/Senior Technical Writer – Oroville Facilities Relicensing Draft Biological Opinion/EFH Consultation, National Marine Fisheries Service, Sacramento, California

As a consultant Mr. Aceituno managed the preparation of a draft ESA Section 7 biological opinion and MSA Essential Fish Habitat (EFH) consultation for the National Marine Fisheries Service (NMFS), Sacramento Area Office, regarding the effects of relicensing the California Department of Water Resources (DWR) Oroville Facilities project by the Federal Energy Regulatory Commission (FERC) on ESA listed salmonids and North American green sturgeon. In addition to providing oversight and supervision to ENTRIX staff, Mr. Aceituno was the senior technical writer for the draft biological opinion and EFH consultation.

Program Manager – ESA Technical Assistance, National Marine Fisheries Service, Sacramento, California

As a consultant to the National Marine Fisheries Service (NMFS), Sacramento Area Office, Mr. Aceituno managed all phases of development of a draft Environmental Assessment and draft programmatic Biological Opinion for ESA Section 10(a)(1)(A) scientific research permits issued by the Sacramento Area office of NMFS. In addition, Mr. Aceituno provided supervision, oversight and senior technical and editorial review during the development of draft ESA Section 7 biological opinions for the Red Bluff Pumping Plant project, Tehama County, California, and the Oroville Facilities FERC relicensing project, Butte County, California. The environmental assessment and draft biological opinions were specifically related to anticipated and potential effects of the proposed actions on ESA listed salmon, steelhead, and green sturgeon and designated critical habitat within the Central Valley and Sacramento-San Joaquin Delta, California. In addition to biological opinions, provided oversight, supervision and guidance on the preparation of draft Essential Fish Habitat (EFH) consultations for these projects relative to Pacific salmon and groundfish and coastal pelagic species, as necessary.

Senior Technical Advisor – Southern California Habitat Conservation Planning, Ventura, California

Provided technical advice during development of ESA Section 10 Habitat

Michael E. Aceituno, Senior Consultant/Fishery Biology

Conservation Plans for the Ventura and Santa Clara Rivers in southern California. Provided review and oversight of ESA related aspects during plan development.

Supervisor Fishery Management Specialist – National Marine Fisheries Service, Southwest Region, Protected Resources Division, Sacramento, California

Mr. Aceituno was the Area Supervisor for the National Marine Fisheries Service, Southwest Regions, Protected Resources Division Office, Sacramento, California, from August 1999 through March 2007. His area of responsibility encompassed the Sacramento and San Joaquin River basin, including the Sacramento-San Joaquin River Delta. Management responsibilities included: 1) providing oversight and supervision to staff biologists conducting ESA Section 7 and Section 10 consultations and Magnuson-Stevens Act EFH consultations for anadromous fishes within California's Central Valley and the Delta; 2) supervising ESA recovery planning and implementation activities for anadromous species within the Central Valley; and, 3) establishing general program goals and providing policy guidance and oversight regarding salmon, steelhead and sturgeon protection, recovery, and management within California's Central Valley and the Delta. This management framework addressed the maintenance of fish habitat along with competing factors such as land use, transportation, utilities, water supply, water quality, flood risk management, levee maintenance, emergency response. These are the same factors that are an integral part of the implementation of a successful Delta Vision.

Conservation Planning & Habitat Restoration Projects

Co-Manager – CALFED Ecosystem Restoration Program, Sacramento, California

Served as a CALFED Ecosystem Restoration Program (ERP) co-manager from 2000 through 2006. Other co-managers for this program included representatives from the California Department of Fish and Game and the U.S. Fish and Wildlife Service. The ERP's primary focus was on ecosystem restoration and recovery and included the Delta and Suisun Marsh. Sustainable ecosystem management of the Delta and Suisun Marsh ecosystem is a key factor in the Delta Vision.

Agency Representative – California Bay Delta Authority, Sacramento, California

Provided leadership, coordination, and oversight while serving as the principle agency representative for the National Marine Fisheries Service on the California Bay Delta Authority from 2000 through 2006.

Agency Representative – Bay Delta Conservation Plan, Sacramento, California

Served as the principle agency representative for the National Marine Fisheries Service on the California Bay Delta Conservation (BDGP) Planning Team, including serving as the principle negotiator for NMFS on the development of the Statement of Principles and the Planning Agreement. The planning framework used in the

BDCP process is similar to that required by Delta Vision.

Agency Representative - San Joaquin River Settlement, Sacramento, California

Served as the principal agency representative for NMFS during the final San Joaquin River Settlement discussion and participated in the development of settlement language and draft legislation for the San Joaquin River Restoration Program. This process dealt with many of the key factors necessary for consideration by Delta Vision, such as aquatic habitat functions, water supply and quality, land use, levee maintenance, and flood risk management.

Water Development And Floodplain Management Projects

Resource Management Agency Representative – Central Valley Project and State Water Project Operations Planning, Sacramento, California

Mr. Aceituno managed and coordinated National Marine Fisheries Service participation in coordinated Central Valley Project (CVP) and State Water Project (SWP) operations planning and implementation. Mr. Aceituno supervised assessments of the effects of CVP/SWP project operations on anadromous fish species, including ESA listed salmon, steelhead and sturgeon. Environmental protection along with water supply reliability was key considerations in this process.

Principle Negotiator – Guadalupe River Flood Management Program, San Jose, California

Mr. Aceituno served as the principle agency negotiator for the U.S. Fish and Wildlife Service (USFWS) on the settlement team developing agreement regarding the Guadalupe River Flood Management Project and environmental protection of the riparian corridor through downtown San Jose, California. This was a collaborative process involving interests and representatives of the USFWS, National Marine Fisheries Service, California Department of Fish and Game, the City of San Jose, the Santa Clara Water Agency, the Army Corps of Engineers, and the Environmental Protection Agency.

Agency Representative – Floodplain Management Non-Structural Solution Assessment Team, Sacramento, California

Mr. Aceituno served as the agency representative for the USFWS on the Army Corps of Engineers Floodplain Management Non-Structural Solution Assessment Team (Team). The objectives of the Team were to analyze and evaluate potential non-structural floodplain management alternatives, such as set back levees and bypasses, for consideration in future flood management proposals and project development.

Fish And Wildlife Evaluation And Assessment Projects

Program Manager – Trinity River Flow Evaluation, Lewiston, California.

Mr. Aceituno managed and prepared analyses on the results of changes in Trinity

Michael E. Aceituno, Senior Consultant/Fishery Biology

River flows relative to salmon and steelhead fisheries, aquatic and riparian habitats. The Trinity River Basin is an important component of the Central Valley Project Water supply. The flow evaluation analyzed a range of flow releases to the Trinity River from Lewiston and Trinity Dams and the observed effects to salmon and steelhead habitat downstream. The objective of the evaluation was to identify a balance that would provide and maintain adequate fishery habitat on The Trinity River while allowing some export of water from the Trinity Basin to the Sacramento Valley provide agricultural and urban water supply through the Sacramento-San Joaquin River Delta to agricultural and urban water users in the San Joaquin Valley and southern California.

Project Manager – City of Stockton, Downtown Marina Redevelopment Project – Biological Monitoring Stockton, California

As the Project Manager, Mr. Aceituno was responsible for managing all phases of biological monitoring for the City of Stockton's Downtown Marina Redevelopment project to ensure compliance with ESA biological opinions. Tasks included study design, planning, budgeting, scheduling and implementation, agency and contractor coordination, documentation, and reporting.

Program Manager – Habitat Conservation and Instream Flow Assessments, various Counties, California.

Mr. Aceituno was the Chief of the Habitat Conservation Division for the U.S. Fish and Wildlife Service, Sacramento Ecological Services Office, Sacramento, California. He managed and supervised field office activities and staff associated with: 1) Federal flood control and water resource development planning and project construction by the U.S. Army Corps of Engineers and Bureau of Reclamation; 2) Federal permitting under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act; 3) energy and power development projects licensed by the Federal Energy Regulatory Commission (FERC); 4) instream flow and habitat assessments in waterways altered by Federal water development projects or Federally licensed for development; and 5) implementation of the Services Coastal Program for San Francisco Bay complex. Duties included: 1) establishing program goals and policy; 2) negotiating funding agreements with Federal, State, and local agencies for Service activities in project planning and technical report preparation; 3) briefing upper level management within the Service and other Federal and State agencies, State legislative staff, and congressional staff on activities within area of responsibility; 4) representing the Service on the State Flood Emergency Action Team, the San Francisco Bay Area Wetlands Planning Policy Committee, and the Interagency Task Force on Levee Repair and Rehabilitation; and 5) supervising a staff of 29 biologists and 5 administrative/clerical support personnel.

Natural Resource Specialist/Fishery Biologist, Bureau of Land Management (now Minerals Management Service), Pacific Outer Continental Shelf Office (POCS), Los Angeles, California

Mr. Aceituno was responsible for planning, conducting, and supervising environmental assessments related to natural resource distribution, abundance and

Michael E. Aceituno, Senior Consultant/Fishery Biology

life history requirements and the biological affects of offshore oil and gas exploration, drilling and production to marine resources, including marine mammals, marine fisheries, benthic and intertidal organisms on the continental shelf off of California, Oregon, and Washington. He also served as the POCS Environmental Coordinator, responsible for the pacific coral management and protection program within the Pacific coastal and Hawaii regions of the outer continental shelf. He prepared multiple Environmental Impact Statement's (EIS's) regarding planned oil and gas exploration leases and was the Contracting Officers Authorized Representative (COAR), providing technical planning, oversight and supervision of intertidal and offshore marine studies necessary to complete environmental assessments and develop management alternatives. Assignments included completing the fishery and marine resource assessments for the Alaska pipeline EIS, and the EIS for the Georges Bank oil and gas exploration program off the east coast of the U.S.

Environmental – Professional Leadership Activities

Supervisor – Protected Resources Division, National Marine Fisheries Service, Sacramento, California

Selected to establish and manage a new office in Sacramento, California. As a senior manager within the southwest region, provided leadership to regional staff and was liaison to headquarters staff and managers regarding anadromous fishery issues within California. Served on various regional and national committees, establishing policy, evaluation potential legislation, and advising senior managers on anadromous fishery and endangered species act issues. Advised Regional and National agency managers and elected officials on actions and procedures implemented within area of responsibility.

Division Chief – Habitat Conservation Division, U.S. Fish and Wildlife Service, Sacramento, California

Selected to manage the Habitat Conservation Division of the U.S. Fish and Wildlife Service, Sacramento Ecological Services Office. Served as a contact with the Regional Office and Headquarters regarding fish and wildlife issues in Central California. As a senior manager within the Field office, assisted in the development of policy, reviewed and evaluated national policy, regulations and proposed legislation advising senior managers and providing leadership to staff.

President – California-Nevada Chapter of the American Fisheries Society, Sacramento, California

Elected by membership to direct the activities of the California-Nevada Chapter of the American Fisheries Society and serve as their representative and liaison to the Western Division and the parent National organization. Chaired the Chapters Executive Committee, established and monitored the budget, planned and coordinated the annual membership meeting.

EMPLOYMENT HISTORY

Michael E. Aceituno, Senior Consultant/Fishery Biology

- Cardno ENTRIX, Senior Consultant, March 2007 to present
- National Marine Fisheries Service, Supervisor Fishery Management Specialist, August 1999 to March 2007
- U.S. Fish and Wildlife Service, Fish and Wildlife Biologist, March 1985 to August 1999
- Bureau of Land Management, Fishery Biologist/Natural Resource Specialist, October 1975 to March 1985
- PEACE CORPS, Volunteer/Fishery Biologist, June 1974 to August 1975
- California Department of Fish and Game, Seasonal Aid, February 1971 to June 1974

DAVID K. FULLERTON

2804 Regina Way
Sacramento, CA 95818

EMPLOYMENT HISTORY

Principal Resource Specialist, Metropolitan Water District of Southern California 2001 – Present

- Recent work focused upon evaluation of various factors possibly linked to fishery declines: phytoplankton, zooplankton, ammonium, flow, salinity, turbidity, temperature, entrainment.
- Studies of smelt/turbidity relationships leading to current RMA smelt behavior model.
- Participation in BDCP, DRERIP technical committees.

Consultant, CALFED 1995 – 2001

- Architect, coordinator of Environmental Water Account

EDUCATION

Stanford University

MS	Electrical Engineering	1983
BS	Physics (With Distinction)	1980
BA	Classics	1980

University of California, Berkeley

MA	Ancient History: Specialty: Ancient Greece	1986
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AWARDS

H100 Leadership Award	California Water Policy 10 Conference	2000
Achievement Award	California Urban Water Conservation Council	1993
Conservation Achievement	CA Water Policy Conference	1992
Phi Beta Kappa	Stanford	1980
National Merit Scholar	Stanford	1975

SELECTED PUBLICATIONS

CALFED: Tinkering at the Edges, Environmental Science and Policy 12 (6), 733-736

Feasibility Study of a Maximal Program of Groundwater Banking. NHI. 12/98. (Coauthor)

An Environmentally Optimal Alternative for the Bay-Delta: A Response to the CALFED Program. NHI. 10/98. (Coauthor)

Breaking the Deadlock Over Water Management in the Central Valley. NHI. July 1995

Summary and Analysis: The Principles of Agreement on Bay-Delta Standards. Hastings West-Northwest Journal of Environmental Law and Policy. V 103. 1995

The California Model in Question. Courier De La Planete. No 24, 1994 (Coauthor)

California Water Policy: Adjusting to New Realities. California Water Law & Policy Reporter. Volume 3, Number 10. July 1993

Optimal Response to Periodic Shortage: Engineering/Economic Analysis for a Large Urban Water District. Anthony Fisher, David Fullerton, Nile Hatch, and Peter Reinelt. California Agricultural Experimental Station Giannini Foundation of Agricultural

Attachment B

Appendix B
Longfin Smelt Distributions

Longfin Smelt Distribution Kodiak, FMWT, and 20 mm surveys														
survey mid-date	>0% and <5% >5% and <10% >10%												black dates = FMWT red dates = 20 mm survey green dates = Kodiak Trawl	
	San Pablo Bay W.	San Pablo Bay E.	Napa River	Carquinez St.	Suisun Marsh	Suisun Bay	Chappa Is.	Lower Sac. R.	Upper Sac. R.	Cache St.	Lwer SJR	nr Franks Tract	E-Delta	
													E-SE Delta	E-Central Delta
9/16/1967	2%	0%	0%	7%	0%	20%	1%	0%	0%	0%	0%	0%	0%	0%
10/21/1967	22%	0%	0%	32%	2%	37%	5%	1%	0%	0%	0%	0%	0%	0%
11/17/1967	0%	16%	2%	3%	10%	52%	11%	5%	0%	0%	0%	0%	0%	0%
12/16/1967	2%	20%	0%	4%	14%	39%	15%	5%	0%	0%	2%	0%	0%	0%
1/18/1968	4%	2%	2%	20%	10%	54%	5%	2%	0%	0%	1%	0%	0%	0%
2/16/1968	0%	4%	7%	7%	8%	75%	3%	1%	0%	0%	1%	0%	0%	0%
3/15/1968	0%	22%	9%	4%	4%	42%	2%	1%	0%	0%	0%	0%	0%	0%
4/17/1968	0%	0%	0%	3%	3%	43%	43%	29%	17%	0%	0%	0%	0%	0%
5/15/1968	0%	0%	0%	3%	3%	4%	56%	34%	3%	0%	0%	0%	0%	0%
10/11/1968	0%	0%	0%	0%	40%	25%	25%	10%	0%	0%	0%	0%	0%	0%
11/1/1968	0%	0%	0%	0%	10%	10%	33%	35%	11%	0%	0%	0%	0%	0%
12/8/1968	0%	5%	0%	0%	11%	52%	17%	7%	0%	0%	5%	3%	0%	0%
1/7/1969	0%	2%	2%	2%	4%	57%	3%	4%	0%	1%	1%	0%	0%	0%
2/4/1969	0%	36%	0%	0%	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%
3/13/1969	7%	24%	0%	16%	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%
4/18/1969	32%	25%	0%	27%	0%	13%	2%	0%	0%	0%	0%	0%	0%	0%
5/15/1969	3%	55%	0%	13%	0%	20%	0%	0%	0%	0%	0%	0%	0%	0%
10/20/1969	1%	1%	0%	0%	8%	82%	7%	0%	0%	0%	0%	0%	0%	0%
11/14/1969	0%	60%	0%	40%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
12/15/1969	5%	13%	0%	13%	10%	45%	11%	1%	0%	2%	0%	0%	0%	0%
1/14/1970	4%	15%	3%	15%	1%	60%	0%	0%	0%	0%	0%	0%	0%	0%
3/16/1970	6%	12%	0%	12%	1%	81%	1%	0%	0%	0%	0%	0%	0%	0%
8/23/1970	80%	10%	0%	0%	1%	30%	42%	1%	0%	0%	0%	0%	0%	0%
9/18/1970	6%	9%	0%	10%	0%	65%	10%	0%	0%	0%	0%	0%	0%	0%
10/17/1970	0%	0%	1%	1%	1%	93%	4%	0%	0%	0%	0%	0%	0%	0%
11/13/1970	0%	1%	1%	14%	9%	65%	9%	0%	0%	0%	0%	0%	0%	0%
12/13/1970	1%	31%	45%	16%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1/15/1971	4%	22%	2%	50%	1%	21%	0%	0%	0%	0%	0%	0%	0%	0%
2/12/1971	0%	27%	0%	10%	2%	75%	1%	0%	0%	0%	0%	0%	0%	0%
3/9/1971	0%	1%	0%	12%	2%	56%	3%	2%	0%	1%	0%	0%	0%	0%
8/11/1971	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9/12/1971	5%	2%	0%	16%	0%	74%	0%	0%	0%	0%	0%	0%	0%	0%
10/10/1971	2%	3%	1%	4%	86%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11/7/1971	1%	10%	2%	11%	9%	30%	22%	14%	0%	0%	0%	0%	0%	0%
12/5/1971	0%	5%	0%	11%	0%	44%	16%	7%	0%	0%	0%	0%	0%	0%
1/17/1972	4%	6%	2%	18%	5%	59%	4%	1%	0%	0%	0%	0%	0%	0%
2/15/1972	0%	0%	0%	0%	0%	38%	39%	7%	0%	4%	11%	0%	0%	0%
3/5/1972	3%	19%	0%	23%	2%	46%	5%	1%	0%	1%	0%	0%	0%	0%
7/11/1972	1%	81%	0%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8/12/1972	0%	2%	0%	44%	0%	4%	9%	4%	0%	1%	0%	0%	0%	0%
9/16/1972	0%	0%	0%	5%	5%	95%	0%	0%	0%	0%	0%	0%	0%	0%
10/14/1972	3%	0%	0%	22%	0%	75%	0%	0%	0%	0%	0%	0%	0%	0%
11/12/1972	0%	1%	5%	5%	76%	12%	2%	0%	0%	0%	0%	0%	0%	0%
12/9/1972	0%	2%	2%	4%	2%	63%	11%	4%	0%	1%	0%	0%	0%	0%
1/13/1973	1%	2%	31%	0%	64%	0%	1%	0%	0%	0%	0%	0%	0%	0%
3/9/1973	6%	76%	3%	14%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
8/15/1973	26%	74%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9/15/1973	2%	3%	2%	3%	2%	70%	20%	0%	0%	0%	0%	0%	0%	0%
10/13/1973	0%	2%	0%	4%	7%	68%	15%	2%	0%	0%	0%	0%	0%	0%
11/12/1973	0%	0%	0%	0%	0%	3%	75%	3%	0%	0%	0%	0%	0%	0%
12/12/1973	0%	17%	20%	21%	3%	3%	1%	1%	0%	1%	0%	0%	0%	0%
1/16/1974	63%	22%	0%	19%	0%	43%	0%	1%	0%	0%	0%	0%	0%	0%
9/18/1975	1%	10%	1%	4%	0%	80%	5%	0%	0%	0%	0%	0%	0%	0%
10/15/1975	0%	0%	1%	1%	6%	84%	8%	0%	0%	0%	0%	0%	0%	0%
11/15/1975	0%	6%	1%	6%	13%	57%	14%	3%	0%	0%	0%	0%	0%	0%
12/14/1975	0%	3%	3%	7%	7%	72%	6%	3%	0%	0%	0%	1%	0%	0%
1/11/1976	0%	11%	0%	13%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11/20/1976	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
1/13/1977	3%	11%	2%	25%	10%	28%	5%	12%	0%	0%	2%	0%	0%	0%
9/16/1977	0%	16%	0%	0%	0%	11%	73%	0%	0%	0%	0%	0%	0%	0%
10/15/1977	0%	0%	0%	0%	0%	5%	69%	0%	0%	0%	0%	0%	0%	0%
11/11/1977	0%	2%	0%	0%	8%	2%	0%	65%	7%	0%	0%	16%	0%	0%
12/9/1977	0%	0%	2%	2%	6%	2%	59%	12%	11%	3%	0%	0%	3%	0%
1/14/1978	0%	15%	26%	46%	2%	4%	5%	0%	0%	0%	0%	2%	0%	0%
3/11/1978	0%	66%	0%	15%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9/16/1978	1%	21%	3%	10%	2%	5%	11%	1%	0%	0%	0%	0%	0%	0%
10/14/1978	0%	1%	5%	5%	73%	13%	1%	0%	0%	0%	0%	0%	0%	0%
11/20/1978	2%	2%	1%	4%	4%	49%	15%	14%	0%	2%	0%	0%	0%	0%
12/15/1978	0%	12%	3%	11%	8%	54%	6%	4%	0%	1%	0%	0%	0%	0%
2/1/1979	0%	5%	0%	3%	5%	54%	2%	0%	0%	0%	0%	0%	0%	0%
9/14/1980	33%	16%	0%	10%	4%	25%	5%	4%	0%	0%	2%	0%	0%	0%
10/13/1980	0%	1%	0%	4%	1%	5%	52%	13%	3%	0%	2%	0%	0%	0%
11/10/1980	0%	0%	1%	20%	47%	16%	15%	0%	1%	0%	0%	0%	0%	0%
12/7/1980	1%	3%	1%	10%	5%	54%	11%	5%	0%	2%	0%	0%	0%	0%
9/24/1981	0%	0%	0%	9%	58%	24%	7%	0%	0%	0%	0%	0%	0%	0%
10/14/1981	1%	2%	0%	0%	10%	5%	9%	72%	0%	1%	0%	0%	0%	0%
11/13/1981	0%	5%	2%	4%	9%	37%	19%	24%	0%	0%	0%	0%	0%	0%
12/11/1981	0%	2%	0%	19%	1%	72%	3%	1%	0%	1%	0%	0%	0%	0%
9/17/1982	1%	31%	0%	5%	3%	54%	3%	0%	0%	0%	0%	0%	0%	0%
10/22/1982	6%	10%	0%	13%	15%	46%	9%	1%	0%	0%	0%	0%	0%	0%
11/11/1982	2%	0%	2%	17%	4%	71%	5%	0%	0%	0%	0%	0%	0%	0%
12/11/1982	2%	13%	0%	26%	2%	55%	1%	0%	0%	0%	0%	0%	0%	0%
9/16/1983	0%	4%	15%	8%	0%	73%	0%	0%	0%	0%	0%	0%	0%	0%
10/14/1983	0%	5%	35%	6%	0%	53%	0%	0%	0%	0%	0%	0%	0%	0%
11/11/1983	0%	11%	10%	18%	7%	48%	6%	0%	0%	0%	0%	0%	0%	0%
12/8/1983	6%	16%	1%	35%	7%	2%	0%	0%	0%	0%	0%	0%	0%	0%
9/13/1984	1%	1%	1%	1%	2%	10%	40%	6%	0%	0%	0%	0%	0%	0%
10/12/1984	0%	30%	1%	15%	5%	33%	9%	3%	0%	1%	0%	0%	0%	0%
11/7/1984	0%	5%	1%	6%	3%	46%	15%	21%	0%	3%	0%	0%	0%	0%
12/5/1984	3%	2%	16%	6%	4%	59%	5%	1%	0%	0%	3%	1%	0%	0%
9/13/1985	0%	0%	0%	17%	18%	13%	24%	9%	0%	0%	0%	0%	0%	0%
9/11/1985	0%	0%	0%	0%	0%	32%	13%	74%	0%	0%	0%	0%	0%	0%
11/6/1985	0%	0%	0%	5%	5%	14%	0%	68%	0%	0%	3%	0%	0%	0%
2/8/1986	1%	0%	0%	1%	2%	72%	27%	1%	0%	0%	0%	0%	0%	0%
9/12/1986	1%	7%	0%	2%	11%	53%	19%	7%	0%	1%	0%	0%	0%	0%
10/10/1986	8%	4%	0%	2%	13%	66%	4%	3%	0%	1%	0%	0%	0%	0%
11/6/1986	0%	13%	1%	5%	10%	45%	12%	13%	1%	0%	0%	0%	0%	0%
12/3/1986	1%	2%	0%	12%	26%	36%	9%	8%	0%	0%	2%	3%	0%	0%
9/11/1987	2%	8%	6%	0%	0%	1%	74%	0%	0%	0%	0%	0%	0%	0%
10/5/1987	0%	0%	3%	24%	0%	26%	27%	0%	0%	0%	0%	0%	0%	0%
11/3/1987	2%	4%	0%	12%	0%	22%	10%	40%	6%	0%	2%	0%	0%	0%
12/11/1987	63%	19%	3%	13%	2%	6%	15%	2%	0%	1%	1%	0%	0%	0%
9/17/1988	0%	0%	0%	19%	0%	17%	65%	0%	0%	0%	0%	0%	0%	0%
10/7/1988	0%	0%	0%	9%	10%	53%	13%	15%	0%	0%	0%	0%	0%	0%
11/11/1988	1%	2%	4%	1%	10%	6%	71%	4%	0%	3%	0%	0%	0%	0%
12/9/1988	7%	1%	2%	4%	1%	2%	39%	5%	13%	0%	3%	3%	0%	0%
9/15/1989	0%	0%	0%	17%	0%	48%	8%	27%	0%	0%	0%	0%	0%	0%

Appendix B

Longfin Smelt Distributions

Longfin Smelt Distribution																
Kodiak, FMWT, and 20 mm surveys																
		black dates = FMWT														
		red dates = 20 mm survey														
		green dates = Kodiak Trawl														
survey mid-date		San Pablo Bay W.	San Pablo Bay E.	Napa River	Carquinez St.	Suisun Marsh	Suisun Bay	Chippis Is.	Upper Sac. R.	Lower Sac. R.	Catche Sl	Laver Sl	nr Franks Tract	SE Delta	ESE Delta	E-Central Delta
9/13/1980	0%	0%	0%	0%	0%	17%	31%	0%	52%	0%	0%	0%	0%	0%	0%	0%
10/5/1980	0%	0%	0%	0%	0%	63%	47%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11/10/1980	3%	12%	0%	5%	5%	12%	1%	52%	0%	0%	9%	2%	0%	0%	0%	0%
12/7/1980	1%	13%	0%	11%	4%	14%	10%	32%	5%	1%	2%	0%	0%	0%	0%	0%
1/10/1991	0%	0%	0%	0%	0%	3%	46%	6%	44%	1%	0%	0%	0%	0%	0%	0%
2/7/1991	0%	0%	0%	0%	0%	4%	38%	3%	54%	0%	0%	0%	0%	0%	0%	0%
3/5/1991	0%	0%	0%	0%	0%	25%	3%	15%	1%	0%	0%	0%	0%	0%	0%	0%
9/13/1991	0%	0%	0%	0%	0%	0%	24%	53%	0%	0%	0%	0%	0%	0%	0%	0%
10/13/1991	0%	0%	0%	0%	0%	20%	53%	18%	10%	0%	0%	0%	0%	0%	0%	0%
11/11/1991	0%	0%	0%	0%	0%	4%	45%	13%	43%	0%	0%	0%	0%	0%	0%	0%
12/6/1991	4%	8%	0%	22%	4%	29%	7%	18%	0%	0%	6%	1%	0%	0%	0%	0%

Longfin Smelt Distribution

Kodiak, FMWT, and 20 mm surveys

survey mid-date	San Pablo Bay W.	black dates = FMWT													
		>0% and <5%					>5% and <10%								
		red dates = 20 mm survey					green dates = Kodiak Trav								
		San Pablo Bay E.	Nipal River	Carquinez St.	Suisun Marsh	Suisun Bay	Chippis Is.	Lower Sac. R.	Upper Sac. R.	Catche St.	Liver SJR	frankia Trust	SE Delta	E-SE Delta	E-Central Delta
5/3/2000	1.2%	3%	0%	59%	3%	62%	13%	4%	0%	2%	0%	0%	0%	0%	0%
5/17/2000	2.1%	1%	0%	59%	1%	36%	3%	0%	0%	0%	0%	0%	0%	0%	0%
5/31/2000	2.1%	3%	5%	41%	1%	50%	4%	52%	0%	0%	0%	0%	0%	0%	0%
6/14/2000	2.1%	0%	0%	30%	0%	36%	1%	0%	0%	0%	0%	0%	0%	3%	0%
6/28/2000	0%	0%	0%	44%	0%	36%	18%	2%	0%	0%	0%	0%	0%	0%	0%
7/12/2000	0%	0%	0%	16%	3%	33%	19%	12%	0%	3%	0%	0%	0%	0%	0%
9/14/2000	0%	23%	0%	10%	0%	6%	1%	1%	0%	0%	0%	0%	0%	0%	0%
10/1/2000	0%	18%	0%	3%	4%	50%	4%	52%	0%	0%	0%	0%	0%	0%	0%
11/1/2000	0%	3%	5%	8%	24%	14%	42%	42%	0%	3%	0%	0%	0%	0%	0%
12/9/2000	0%	1%	5%	13%	0%	43%	13%	22%	0%	2%	0%	0%	0%	0%	0%

Longfin Smelt Distribution Kodiak, FMWT, and 20 mm surveys	
	black dates = FMWT red dates = 20 mm survey green dates = Kodiak Trawl
survey mid-date	
San Pablo Bay W.	
San Pablo Bay E.	
Napa River	
Carquinez St.	
Suisun Marsh	
Suisun Bay	
Chippis Is.	
Lower Sac. R.	
Upper Sac. R.	
Cadute St.	
Lewis S.R.	
nr Frances Tract	
SE Delta	
E-SE Delta	
E-central Delta	